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UNIVERSITY OF CALIFORNIA SAN DIEGO

The Nature and Evolution of Center-Embedding:
A Multi-Disciplinary Approach

A dissertation submitted in partial satisfaction of the requirements
for the degree Doctor of Philosophy

in

Linguistics, with a Specialization in Anthropogeny

by

Emily Davis

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2023

The dissertation of Emily Davis is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

University of California San Diego

2023

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LIST OF ABBREVIATIONS/GLOSSES

1	first person
2	second person
3	third person
ABIL:	abilitative
ABL:	ablative
ACC:	accusative case
ADJ:	adjective
ADN:	adnominal
COND:	conditional
COMP:	complementizer
CONJ:	conjunction
CONT:	continuous
COP:	Copula
DAT:	dative case
DECL:	Declarative
DEM:	Demonstrative
DEF:	definite article
FEM/F:	feminine
FUT:	future
GEN:	genitive case
INDEF:	indefinite
INESS:	inessive
INF:	infinitive
INSTR:	instrumental
IPFV:	Imperfective
MASC/M:	Masculine

MD: (prenominal) modifier, in Korean

NEG: negative

NEUT: neuter

NOM: nominative case

NMNL: Nominalizer

PART: Partitive

PASS: passive

PL: Plural

POSS: Possessive

PRES: present

PRF: perfective

PROG: progressive

PST: past

PTCP: participle

QT: quotative

REFL: reflexive

REL: relative

SG: singular

SBJV: subjunctive

TOP: topicalizer

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ACKNOWLEDGEMENTS

Many thanks to the colleagues and mentors who helped me develop this dissertation:

My advisor Robert Kluender for his constant support and feedback in this incredibly difficult project.

Ivano Caponigro, Karine Megerdooomian, Dukho Jung, Hagyeong Shin, Seoyeon Jang, Nese Demir, Ezra Van Everbroeck, Maho Takahashi, and Masayuki Asahara, for their generous assistance in glossing and translation.

Arturs Semenuks, for assistance with corpus research.

Jeffrey Xing, Colin Trimmer, Mike Turvey, Anna Mai, Kai Chen, and Trevor MacPherson at the Gentner Lab, for assistance with bird research. Without them Chapter 6 would not have been possible.

My parents and my best friend D., for keeping me sane.

The birds.

Chapter 4 has been submitted for publication:

Davis, Emily and Smith, Kenny (forthcoming). The learnability and emergence of dependency structures in an artificial language. To appear in *Journal of Language Evolution*.

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Fields of Study

Major field: linguistics

ABSTRACT OF THE DISSERTATION

The Nature and Evolution of Center-Embedding:

A Multi-Disciplinary Approach

by

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This dissertation presents a survey of center-embedding across languages, the factors involved in the processing difficulties, and implications for the evolution of human language.

First, I discuss prior typological, experimental, and theoretical research on syntactic center-embedding, with a particular focus on how its acceptability and processability differs between SVO languages and SOV languages. The evidence shows that both universal factors and language-specific factors are involved, including clause types, referential form of subjects, and case marking.

Building on this cross-linguistic survey, I present the results of a corpus study demonstrating that center-embedding is more common in verb-final languages. In addition, I

examine sentences from the corpus search, and other observed English examples of multiple center-embedding, with regard to the facilitating semantic and syntactic factors observed in experiments.

In addition to linguistic data, I report on experimental results including a series of nonlinguistic iterated sequence learning experiments intended to elicit the formation of center-embedding. While embedded structures did appear, they rarely showed up at more than chance rates, but there were (sometimes significant) differences between conditions. Specifically, repeated icons in initial strings did seem to prompt the formation of embedding.

Additionally, I report on a pair of artificial language experiments involving dependency structures. The results suggest that center-embedding is particularly hard to process, possibly even harder than crossed dependencies (which are very rare in natural language). The results thus stand at odds with natural language typology.

Next I put these findings into a broader perspective, exploring the roots of center-embedding in nonlinguistic (and not exclusively human) cognitive abilities. Based on a range of observational and experimental evidence, I argue that center-embedding is an inheritance from nonlinguistic cognition, limited in its scope in language by specific features of language (i.e. time pressure and semantics). Drawing on previous animal cognitive research, I present the results of another novel experiment, an attempt to teach birds to recognize a form of simple center-embedded pattern; one subject showed signs of successful learning.

Finally I discuss the greater implications of these findings for the evolution of center-embedding in particular and language evolution in general.

Introduction

This dissertation sets out to offer a broad overview of the linguistic phenomenon of center-embedding, and its relevance to the evolution of human language. I take an interdisciplinary perspective covering experiments, corpus studies, and observations of human and animal behaviors, along with naturalistic center-embedded sentences. My goal is to explore the factors that make center-embedding more or less difficult to process, and its possible evolutionary basis in nonlinguistic cognitive abilities. Center-embedding, especially multiple center-embedding of clauses, is usually assumed to be difficult to process, but this difficulty can be mitigated by various factors such as clause type and subject type; furthermore, the prevalence and acceptability of also center-embedding varies across languages depending on specific factors word order and morphology. Furthermore, despite its seemingly problematic status in language, center-embedding and analogous patterns are ubiquitous in human nonlinguistic cultural artifacts and behaviors, and arguably some animal artifacts and behaviors as well. These wide-ranging observations imply a prelinguistic evolutionary origin for recursion and its exaptation into language from extralinguistic cognition; in the process of being exapted into language, center-embedding is also reduced in depth and prevalence, due to the exigencies imposed by real-time language use and semantic meaning.

By way of introduction I will explain the syntactic phenomenon at hand (section 1), and the ways in which it is significant to linguistics (section 2) – and in particular its relevance to longstanding questions about language evolution (section 3), before summarizing the chapters that follow (section 4).

1. What is center-embedding?

I define center-embedding as a linguistic structure in which one constituent (A) is embedded in another constituent (B), such that material from B is on both sides of A. This is illustrated abstractly in (1) and with a center-embedded object relative clause in (2):

1. B1..A..B2
2. [C1 The dog
 [C2 the cat likes]
 chased the squirrel]

In this and subsequent examples with center-embedded clauses (the structure I will generally focus on), I will notate the main clause in a sentence as “C1” and the clause that is center-embedded within C1 as “C2,” and so on for any deeper levels of embedding that exist. (3) has two levels of center-embedding, whereas (2) above has only one, the embedded clause C2. In (3) I have also marked and indexed the gap positions at which the relativized nouns must be interpreted:

3. [C1 The dog₁
 [C2 the cat₂
 [C3 the bird hates _₂]
 likes _₁]
 chased the squirrel.]

In a sentence like (2) or (3), the separated elements of a subject-verb pair such as “the dog... chased” then form a *long-distance dependency* that is interrupted by another (embedded) clause. Likewise, the relativized filler nouns (“the dog” and “the cat”) are separated from the gap positions at which they are interpreted in the relative clause, forming another type of dependency (Fodor 1978). The length of these dependencies and the fact that the dependencies in an embedded constituent must be processed while others are still open contribute to the processing difficulty presented by center-embedding; I will discuss these factors more extensively in Chapter 1.

In defining center-embedding, I will briefly discuss which types of constituents can be center-embedded and the scope of this study in particular (1.1), and how center-embedding differs from other possible dependency structures (1.2).

1.1. Constituent types and self-embedding

Different types of linguistic constituents can be center-embedded: relative clauses (as above), complement clauses of nouns or verbs, noun/determiner phrases, and adpositional phrases. Herein I will focus on cases of what is also called *self-embedding* (the term used by Chomsky 1965: 12), in which the embedded constituents A and B are of the same type (e.g. a clause embedded within another clause, or a noun phrase embedded within another noun phrase). This form of center-embedding has attracted considerable linguistic attention both for the processing difficulties it seems to present, as well as for its theoretical significance. From here on out, I will refer to this construction simply as *center-embedding*. In keeping with the general trends of prior research, my focus will mostly be on center-embedding of clauses, and particularly relative clauses, but I will also address center-embedding in noun phrases and adpositional phrases in Chapter 4.

1.2. Center-embedding and other dependency structures

Center-embedding can be distinguished from other dependency types, namely branching and crossed dependencies. Dependencies between linguistic elements can be right-branching (4) or left-branching (5); in these cases the syntactically subordinated constituent comes entirely after or before its “parent” constituent (Chomsky 1965: 12):

4. The box [on the shelf [in the garage]] (right-branching)
5. [[The teacher’s] daughter’s] friend (left-branching)

Finally, dependencies can be crossed. In this case, the first elements of all dependencies are concatenated, and the second elements are in the same order (A1 B1 A2 B2). This phenomenon is rare in natural languages; few examples are attested, specifically in certain constructions in Dutch (Bresman et al. 1987), Swiss German (Schieber 1985), and Tagalog (MacLachlan & Rambow 2002). However, there is some evidence from processing and artificial language learning experiments that crossed dependencies may be easier to process than equivalent center-embedded dependencies (see Chapter 4 for more details).

Figure 0.1 shows a visual representation of center-embedding (b) contrasted with two other dependency types: right-branching (a) and crossed (c). Center-embedding, as already described, refers to a linguistic structure in which a dependency is embedded inside another of the same or a similar type, interrupting the higher dependency.

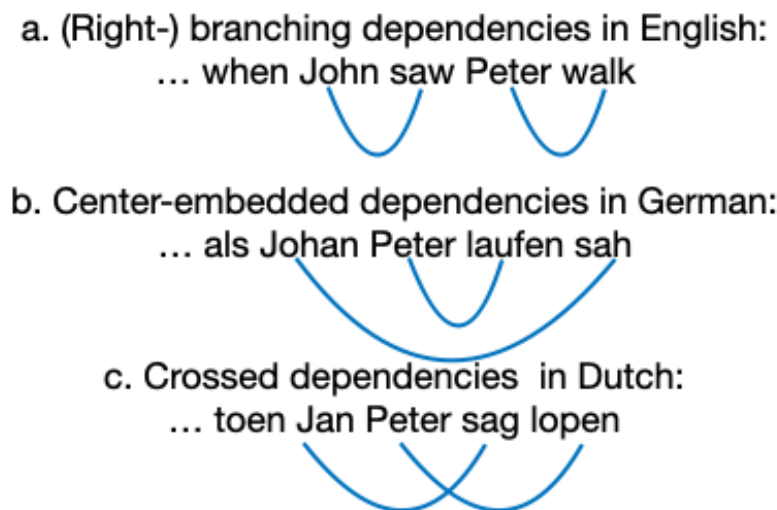


Figure 0.1: Comparison of dependency types with English, German, and Dutch examples, after Vosse & Kempen (1991). All sentences are glossed “when John saw Peter walk.”

2. Why is center-embedding interesting?

Center-embedding has attracted a great deal of interest since the early days of modern linguistics (Chomsky 1957, Chomsky & Miller 1963). This phenomenon is closely connected to

several important concepts across different subfields of linguistics, and relates to several major questions concerning the evolution and cognitive basis of human language itself. In this section I will explore some of these concepts.

First, the existence of center-embedding is relevant to the formal properties of human language, with possible implications for differences (or similarities) between human and animal cognition. The existence of center-embedded dependencies confirms that human language requires a context-free grammar or one more complex, as opposed to a finite-state grammar, which cannot handle multiple long-distance dependencies. These formal aspects of center-embedding are summarized below in Section 2.1.

However, while center-embedded sentences can be generated through recursive application of grammatical rules, they are not necessarily amenable to comprehension and processing. Therefore, observations and experiments with sentences containing multiple clausal center-embeddings can offer insights into on-line processing and parsing, and the role of working memory, as briefly summarized in Section 2.2 below.

Finally, as I will explore in Section 3, center-embedding relates to the ever-contentious issue of recursion, and consequently to deep questions about the cognitive basis, uniqueness, and evolutionary background of human language. Observational and experimental evidence suggests that recursive center-embedding is not unique to either language or human cognition, which I will explore more fully in Chapter 5.

2.1. Center-embedding and formal grammar

The theoretical importance of center-embedding is closely linked to the Chomsky Hierarchy, which classifies formal languages by their complexity, i.e. the types of rules they allow (Chomsky 1957:22, Hunter 2021).

To explain the role of center-embedding in formal languages, it is first necessary to define some important concepts. A formal language constitutes a set of rules for generating strings from a lexicon of symbols. A terminal symbol is one that cannot be converted into any other symbol, whereas a nonterminal symbol can be converted by a rule. Rules take the form in (6), where A is a nonterminal symbol and B may be a string of any length, including zero, consisting of terminals and/or nonterminals.

$$6. A \rightarrow B$$

In this classification, center-embedding distinguishes context-free grammars from finite-state grammars, which support iteration (the repeated application of a rule adding an element to the end of a string) but not multiple center-embedded dependencies. Specifically, a finite-state grammar can contain rules of the form in (7), where S is a non-terminal symbol and a is a terminal symbol:

$$7. S \rightarrow Sa$$

Such a grammar cannot keep track of whether the left and right sides of the expression match, as it can only add new elements to the right end of the string (Hunter 2021: 84). Context-free grammars, on the other hand, allow for rules of the form in (8a), which can be recursively applied to form balanced sequences as in (8b):

8.

$$a. S \rightarrow aSb$$

b.

aSb

$aaSbb$

$aaaSbbb$

Rules of this sort can also produce palindromes (9a) and strings of matched brackets (9b):

9.

a. $S \rightarrow aSa; S \rightarrow bSb$

S
aSa
abSba

b. $S \rightarrow \{ \} ; S \rightarrow [S] ; S \rightarrow \langle S \rangle$

{ }
[{ }]
< [{ }] >

(based on Hopcroft & Ullman 1979: 103)

Since finite-state grammars can only add new elements to the end of the string, they cannot keep track of multiple nested sets of “brackets,” although finite-state grammars can produce strings that contain a single long-distance dependency. Single dependencies are a necessary, though not sufficient, condition for nested embedding (Rogers & Pullum 2006, Rohrmeier et al. 2015). Center-embedded structures, or any structures with multiple long-distance dependencies, therefore, cannot be generated with a finite-state grammar.

Thus, syntactic center-embedding is important to the question of the formal properties of human language, and the existence of (theoretically) unlimited center-embedding in human language grammars makes it clear that human languages are not limited to finite-state grammar, but require (at least) a context-free grammar.¹ However, not every sentence that can be generated by the grammar of a human language can be easily processed or understood by real speakers, and this is the next issue I will turn to: the relevance of center-embedding to processing and why it may present difficulties.

¹ The presence of crossed dependencies in some human languages has been taken to indicate that human language actually requires a *context-sensitive grammar*, which is more complex than a context-free grammar. For more on these issues see Pullum and Gazdar (1982), Gazdar and Pullum (1985), Partee et al. (1990), and the introduction to Chapter 4 .

2.2. Center-embedding and real-time language processing

Center-embedding is also of considerable interest to psycholinguistics and the study of language processing. Sentences with multiple center-embedded clauses are known to present a challenge for real-time processing, and therefore shed light on how sentences are processed in conjunction with working memory. However, the difficulty of processing multiple center-embedding has been somewhat exaggerated, as I will explore in the first two chapters with regard to experimental evidence, observed examples, and corpus data.

As explained above, center-embedded structures involve long-distance dependencies (e.g. between a subject and verb) separated by an intervening structure (such as a relative clause). This separation of dependency elements, along with the burden of processing intervening material while holding the open dependency in memory, may make center-embedded structures hard to process. The difficulties of processing multiple center-embedding have been observed often, since the earliest days of psycholinguistic research (Miller 1962, Miller & Isard 1964, Blumenthal 1966, Fodor & Garret 1967, , Foss et al. 1970, Blauberg et al. 1974). In a sentence with two center-embedded clauses, there are two pairs of long-distance dependencies, and in processing the sentence, multiple unfinished dependencies must be kept in mind at once. As observed by Miller & Isard (1964), speakers' "capacity to deal with recursive interruptions" – i.e. multiple center-embedded clauses – seems to be limited, but this observation must be qualified with regard to the nature of these interruptions, i.e. the lexical and syntactic properties of the embedded clause. I will discuss these processing issues in more detail below, particularly in Chapter 1, Section 2.

In the process of reading or hearing a sentence, words are held in working memory. In a sentence with a relative clause, like (10), the filler (Fodor 1978, e.g. *the cat*) will be retrieved

when the reader/listener arrives at the gap position in the embedded clause (after *chased*) (Lewis et al. 2006, Dotlačil 2021). The parsing mechanism postulates a gap as soon as any evidence for a gap appears – e.g. a relative clause marker – and “wants” dependencies resolved as soon as possible, to save on memory (Keshev & Meltzer-Asscher 2020). This makes sentences like (10) challenging for processing:

10. The cat ₁
 [C2 the dog₂
 [C3 the man walked ₂]
 chased ₁]
 is angry

In (10), not only must a center-embedded relative clause C2 (*the dog... chased*) be processed before the main clause predicate is reached, but the relative clause C2 is interrupted by its own center-embedding C3. The processing difficulties presented by sentences like this, the factors involved in lessening or exacerbating this difficulty, and the phenomenon of grammaticality illusions as further evidence for processing challenges, are extensively explored in Chapter 1 – along with evidence for the role of both universal cognitive factors and language-specific factors.

Adding another layer of center-embedding, in the form of a new clause C4 embedded in C3, makes the sentence almost incomprehensible:

11. [C1 The cat ₁
 [C2 the dog₂
 [C3 the man₃
 [C4 the girl knows ₃]
 walked ₂]
 chased ₁]
 is angry.]

The difficulty involved in real-time processing of center-embedded sentences, especially those with multiple nested object relative clauses, like (10) and (11), has long interested psycholinguists. As Fodor et al. (2017) note, extremely hard-to-process sentences made it

possible to observe differences in processing at a time when precise measures of factors like reading time were not available, offering a clearer window into the comprehension process. Some important factors and related phenomena for the processing of center-embedding are explored in Chapter 1. A wide variety of parsing models (e.g. Frazier & Fodor 1978, Fodor 1978, Stowe et al. 1991, Gibson 1998, Gibson 2000, Lewis & Vasishth 2005), and other principles of sentence processing (e.g. Kimball 1973) have been proposed with attention to the particular difficulties posed by center-embedding. Generally speaking, based on observational and experimental evidence, center-embedding is easier to process (e.g. faster reaction times, better comprehension, and less susceptibility to a grammaticality illusion) if the embedded clauses are shorter, and introduce fewer new referents and fewer and shorter dependencies.

3. Center-embedding, recursion, and the evolution of language

Center-embedding is also closely related to recursion, which is a contentious aspect of human language and its evolutionary and cognitive basis. Recursion may be defined for our purposes as follows (Fitch 2014): “that broad class of computational processes in which a function calls itself (in computer science), or to those structures where the same hierarchical structure is repeated at multiple levels of the hierarchy (self-embedding).” For example, if a rule allowing a clause to be inserted into another clause (e.g. as a complement) is recursively applied, a repeated hierarchical structure results; center-embedding is one such structure that can be generated in this form, along the alternative forms of branching described previously in Section 1.2.

The phenomenon of recursion is also linked to another important issue: the relevance of center-embedding to the evolution and cognitive basis of human language. Recursion is relevant to the controversial issues of how language is related to other domains of human

cognition, and how these human cognitive abilities relate to and differ from the cognitive and communicative abilities of other species. I will summarize the relevant issues briefly below, and explore them in more detail in Chapter 5.

Much debate around language evolution has been sparked by the question of recursion, and whether it is unique to language and/or human cognition. Hauser, Chomsky, and Fitch (2002) threw down the gauntlet. These authors made the strong claim that recursion is unique to the language faculty, and to humans – i.e. that recursion is unique to the faculty of language in the narrow sense (FLN) and does not occur in animal cognition or any animal communication systems. However, HCF briefly suggest the possibility of a prelinguistic origin for linguistic recursion in abilities such as navigation, social cognition, and numerical ability (2002: 1571). In more recent research, these twin uniqueness claims have been challenged based on new (and some older) observations of animal and human cognition, and there is stronger evidence for the hypothesis that recursion is prelinguistic, based on the observation of center-embedded recursive patterns in nonlinguistic domains of both human and animal behavior and cognition. This evidence comes from multiple disciplines as diverse as music theory and animal behavior, which I will explore extensively in Chapter 5. Based on this evidence from different disciplines, I suggest that linguistic recursion is an inheritance from center-embedding processes in nonlinguistic cognition which appear in nonlinguistic human cognition and have parallels in animal behaviors.

4. Overview of the following chapters

The structure of this dissertation is as follows: Chapter 1 presents an extensive overview of prior typological and experimental research on center-embedding across English and other languages (specifically the Romance languages, Japanese, and Korean), the factors that contribute to its processing difficulty, and how its acceptability varies cross-linguistically. The

conventional wisdom that center-embedding is universally difficult and unacceptable does not hold up to evidence, as some center-embedded sentences are quite processable. Factors that affect the processability of center-embedding are generally those that reduce the amount of new referents in the embedded clauses, shorten dependency length, or reduce similarity between confusable constituents (e.g. the subjects of the embedded clauses). The missing VP effect, a grammaticality illusion, also demonstrates how the comprehensibility of center-embedding is impacted both by general working memory issues (e.g. interference) and language-specific factors.

I continue this line of research in Chapter 2, in which I present the results of a cross-linguistic corpus study using the Universal Dependencies tagged corpora to search for center-embedding. These results reveal an interesting cross-linguistic and typological difference in the prevalence of multiple center-embedding: namely, it is much more common in languages with verb-final syntax than in other types. In addition, I analyze some observed English examples of center-embedding (along with sentences from other languages found in the corpus searches) with regard to the parameters that have been observed to facilitate processing, and show that the experimentally observed factors also hold up in natural discourse.

In addition to this overview of linguistic center-embedding, I have conducted several experiments in the cognitive processing of center-embedding patterns, linguistic and otherwise, by humans and avians.

Chapter 3 discusses a series of iterated learning experiments involving nonlinguistic sequences of icons, designed to elicit the potential emergence of center-embedding or assess the learnability of center-embedded patterns. In the results, center-embedded patterns generally did not appear from initially unstructured input at levels above chance, and such patterns did not persist when initially introduced. However, it is also apparent that the presence of a repeated

character in the strings seen by the first participant, creating a simple dependency, may “seed” center-embedding in subsequent generations. The relative rarity of center-embedding in the results also demonstrates the role of working memory constraints in limiting center-embedding, in nonlinguistic sequences as well as language.

Chapter 4 reports on a pair of artificial language learning experiments involving different dependency structures: consistent branching, crossing and center-embedding. The results suggest that center-embedding is the hardest dependency pattern to learn in a small-scale artificial language. Furthermore, some evidence from the results suggests that the (rare in natural language) crossed dependency structure is actually more learnable than center-embedding. This surprising outcome supports the hypothesis that center-embedding, though widespread in language, may be poorly adapted to it, which supports the notion that center-embedding is a carry-over from other fields of cognition and limited in language due to the constraints of real time processing.

Chapter 5 is an overview of center-embedding in nonlinguistic domains, human and nonhuman, and its possible implications for the origin of linguistic center-embedding. First, there is evidence that recursive center-embedding is not unique to language within human behavior and culture. The insight that recursion and center-embedding occur in domains besides language – including music and everyday tasks – has been made several times, apparently independently (e.g. Hofstadter 1979, Staal 1984, Fitch & Martins 2014, Pulvermüller 2014). The independence of these observations itself attests to the ubiquity of recursive structure in human culture. Of particular interest are the relatively little-known findings of the Indologist Frits Staal, who observed that ancient Vedic rituals show an embedded structure akin to that which is essential to human language. Specifically, Staal noted that performances of one Vedic ritual can be center-embedded in another (Staal 1979:16), much like the constituents of a sentence.

Importantly, center-embedding also occurs in many domains of nonlinguistic human activity, including the structures of music and visual art – all of which are ultimately tied to ritual. While center-embedding in action sequences can be of effectively unlimited depth (Pulvermuller 2014), it is well-known that syntactic center-embedding is limited (Karlsson 2007). This discrepancy implies that center-embedding was exapted to language from more general action planning, i.e. the ability to carry out complex tasks with subtasks, and reduced in language due to the constraints imposed by both real-time processing and the need to track semantic information.

Other evidence for the prelinguistic nature of recursive cognition, though more tentative, comes from animal behavior and cognition. Some animal communications and behaviors, such as mating dances, show a very simple embedded structure that can be formalized as A-B-A, in which one distinctive action “brackets off” some ritualistic behavior, e.g. for courtship. In addition, primates and songbirds can learn to recognize or produce strings based on center-embedded rules. While the interpretation of these observations and experimental results is not always clear, and in many cases only a minority of the animal subjects learn recursive patterns successfully, they provide interesting evidence for the prelinguistic basis of linguistic recursion.

Following up on the animal experiments summarized in the previous chapter, Chapter 6 presents the results of an experiment following up on the important work of Gentner et al. (2006) and Abe & Watanabe (2011), who determined that songbirds were capable of learning to recognize some types of center-embedded patterns in auditory sequences. I have tested the ability of starlings to learn to recognize and generalize another type of simple center-embedded pattern, and I report on one bird’s successful performance.

The general picture that emerges is as follows: Recursion in language, and specifically center-embedding, are inherited from non-linguistic cognitive faculties related to subgoaling and complex task-planning. Multiple center-embedding is problematic in language for reasons related to working memory and the processing burdens associated with semantic meaning, which are not issues in longer-term rituals and action sequences. Syntactic center-embedding is sometimes replaced by new structures, namely consistent branching and occasionally crossed dependencies (but still appears in some languages more than others). Compared to center-embedding in nonlinguistic cognition and action, linguistic center-embedding is “vestigial,” held back by the time constraints imposed on language as well as the need to process semantic content.

Chapter 1: Typological and experimental research on center-embedding

This chapter is a survey of prior research regarding the degree to which center-embedding is tolerated across different languages. In the first subsection I discuss the general tendency of languages to avoid center-embedding, primarily with regard to clauses, and some striking counterexamples. Sections 2-4 review existing research on center-embedding in languages of two syntactic categories: SVO languages such as English (2), other SVO European languages (3), and SOV languages such as Japanese and Korean (4), with attention to the features which mitigate or add to the difficulty of center-embedding in these languages. This raises the question of whether the latter may allow more center-embedding than the former, because complement clauses will usually be center-embedded, as are relative clauses modifying the object of the verb. Furthermore, tolerance for center-embedding may be affected by morphological factors, such as verb inflection and case marking, in both types of languages. I also address (1.5) the “missing VP” illusion as a cross-linguistic phenomenon that illuminates the variety of language-universal and language-specific factors relevant to the acceptability of center-embedding; this processing error may be less prevalent in languages that allow verb-final order and thus more center-embedding.

English is no doubt the best-studied language with regard to center-embedding and the factors that affect its difficulty, primarily concerning embedding of clauses. Many early studies, following up on Chomsky & Miller (1963), showed that, although center-embedded structures are legitimately generated and licensed by the grammar, English speakers have difficulty processing and understanding multiple clausal center-embeddings. Sentences with doubly embedded object relative clauses are particularly difficult (Fodor & Garret 1967, Blaubergs & Braine 1974, Foss et al. 1970), and speakers may perceive them as ungrammatical even though they are generated by the grammar (Blumenthal 1966, Marks 1968). These findings led to the common assumption that clausal center-embedding beyond one level is inherently hard to process, not only in English but in all languages. Kimball (1973) formalized this concept as the

“principle of two sentences”: it is not possible to parse components of more than two sentences simultaneously, such as the three consecutive subject noun phrases and three consecutive verbs of center-embedded clauses in (1).

1. [C1 The mouse _a
 [C2 the cat _b
 [C3 the dog worried _b]
 killed _a]
 ate the malt.]

However, some researchers have called this assumption into question by citing found examples of sentences with two levels of center-embedding (e.g., De Roeck et al. 1982, Sampson 2001), or observations of interlocutors comprehending center-embedding without any issue (Labov 1973: 102).

Relatedly, it has been assumed that languages tend to avoid center-embedding by way of either obligatory or optional syntactic rules; the accuracy and limitations of this assumption will be discussed below in Section 1.1.

1.1. How languages avoid center-embedding (or don't)

As mentioned in the Introduction, center-embedding of constituents of the same type (primarily clauses) is assumed to present difficulties for processing and comprehension, and the difficulty that multiple center-embedding poses for processing is fairly well-established.

Therefore, it logically follows that languages would tend to avoid center-embedding, whether through fixed word order rules that prevent it from arising, or processes that alter the default word order, such as extraposition. As I will demonstrate, there is some truth to this generalization, but it is far from universal.

This section is a brief overview of how center-embedding comes about through combinations of word order rules, and how languages may or may not prevent it from occurring. For example, SOV order produces center-embedding of complement clauses by default. These syntactic rules will be described in Section 1.1.1, and in the following section 1.2.2, I will give an

overview of how languages may avoid problematic center-embedding. For example, languages may use extraposition or word order variation to prevent center-embedding in some or all cases where it would occur. However, there are some striking counterexamples to these tendencies, which will be discussed in Section 1.1.3.

1.1.1. Embedding and word order rules

Center-embedding, as defined in the Introduction, is a syntactic form in which a constituent (e.g. clause) is embedded inside another of the same type, such that material from the “outer” constituent appears on both sides of the inner, embedded one. This structure follows from certain combinations of word order rules, and to avoid center-embedding, languages may either exclusively employ rules that do not produce it, or allow exceptions to their usual word order. Rules that cause center-embedding include verb-final order, which results in center-embedding of complement clauses, and when combined with postnominal relative clause order, all relative clauses are center-embedded as well.

In verb-final languages, complement clauses (of verbs with meanings like *to think*, *believe*, *know*) will be center-embedded if default word order is maintained, as demonstrated in the abstract examples in (2). In (2a), a clause C2 is embedded between Subj1 and V1, the subject and verb of the main clause C1. In (2b) the same pattern is applied recursively, inserting another clause C3 into the embedded clause C2.

2. Center-embedded complement clauses

- a. [_{C1} Subj1 [C2] V1]
- b. [_{C1} Subj1 [_{C2} Subj2 [C3] V2]] V1]

The Korean sentence (3), with two layers of center-embedding, corresponds to structure (2b):

3.

[C1 Sunhi-nun
[C1 S -Top
[C2 Chelswu-ka
[C2 C -Nom
[C3 Yenghi-ka uless-tako]
[C3 Y -Nom cried-that]
malhayss-tako]
said -that]
mitnunta]
believes]
"Sunhi believes that Chelswu said that Yenghi cried." (from Hagstrom & Rhee 1997)

This structure for complement clauses is seen in SOV languages including Japanese, Korean, and Turkish, and its prevalence will be explored more extensively in Chapter 2.

The placement of relative clauses with regard to the nouns they modify also affects the appearance of clausal center-embedding. In many SOV languages, such as Japanese, relative clauses are prenominal (Dryer 2013). Kuno (1974: 120) notes that this order prevents center-embedding for clauses modifying the subject, as illustrated in (4). If relative clauses are prenominal (RelN), then only those modifying the object of a transitive verb are center-embedded, as in (4a).

4. SOV + RelN:

- a. Intransitive: [Mary loved ____] boy died
'The boy that Mary loved died'
- b. Transitive subject: [Mary loved ____] boy Jane hated
'The boy that Mary loved hated Jane'
- c. Transitive object: Jane [Mary loved ____] boy hated = center-embedding
'Jane hated the boy that Mary loved' (examples adapted from Kuno 1974)

On the other hand, in a verb-final language with postnominal relative clauses (NRel), all relative clauses that modify the subject NP would end up center-embedded as in (5):

5. SOV + NRel:

- a. Intransitive: boy [Mary loved ____] died = center-embedding
'The boy that Mary loved died'

- b. Transitive subject: boy [Mary loved ____] Jane hated = center-embedding
'The boy that Mary loved hated Jane'
- c. Transitive object: Jane boy [Mary loved ____] hated = center-embedding
'Jane hated the boy that Mary loved' (examples adapted from Kuno 1974)

The prevalence of prenominal relative clauses in SOV languages may actually be an adaptation to lessen the frequency of center-embedding, as it avoids embedding relative clauses that modify the subject in between subject and verb. In addition, languages may use exceptions to their normal word order to displace clauses from a center-embedded position, making the sentence more processable.

1.1.2. Syntactic methods for avoiding center-embedding

In addition to fixed word orders that prevent center-embedding from occurring, some languages allow deviations from their usual word order to avoid center-embedding where it would normally occur, such as extraposition. This process occurs widely across languages with sentential noun phrases. In languages where normal word order would force such clauses to occur center-embedded within the main clause, they may be extraposed to an initial or final position, either as a preferential order or a strict grammatical rule (Dryer 1980).

Cross-linguistically, the clause-internal position for sentential NPs and complement clauses is least favored – i.e. it is ungrammatical in some languages and permitted but uncommon in others. I will illustrate with a few examples from English, German, and Persian.

For example, in English, sentential NPs cannot occur center-embedded within questions as in (6a), but must be extraposed as in (b):

- 6.
 - a. *Is [that Donald is stupid] clear?
 - b. Is it clear that [that Donald is stupid]?

Similarly, German requires extraposition of center-embedded complement clauses with finite verbs to clause-final, although, as will be discussed in the following subsection, it does allow center-embedding of complement clauses elsewhere:

7.

- a. *Ich denke, dass [dass die Erde rund ist], deutlich ist
'I think that [that the earth is round] is clear.'
- b. Ich denke, dass es deutlich ist, dass die Erde rund ist. (Kuno 1974)

Some languages do not allow complement clauses to ever occur in a center-embedded position. Persian has obligatory extraposition of all complement clauses, e.g. for verbs like “to know” (8). Under normal SOV word order, these clauses would occur within the main clause, but this position is ungrammatical; unlike normal objects, sentential objects / complement clauses must be clause-final (Hawkins 1994: 11):

8.

- a. *An zan [ke a mard sangi partab kard] mi danat
That woman [COMP that man rock threw] CONT know.3sg
- b. An zan mi danat [ke an mard sangi partab kard]
That woman CONT know.3sg [COMP that man rock threw]
'The woman knows that the man threw a rock'

However, such tendencies against center-embedding are not universal, and what may be impermissible in one language may be fully acceptable in another. I will discuss some cases where center-embedding is allowed or indeed obligatory in the next section.

1.1.3. Counterexamples: when center-embedding persists

Some natural language data suggests that the constraints discussed above are not absolute – there are languages that permit word orders that generate multiple center-embedding of noun phrases or clauses, and in which a non-center-embedded order is ungrammatical. This is particularly true of SOV languages but not limited to them.

For example, there is an interesting case of a language with obligatory DP center-embedding, which also results in clauses becoming center-embedded. The extinct indigenous American language isolate Coahuilteco, known from a 17th century colonial Spanish religious manual, featured SOV syntax and the noun phrase order N Rel Det (Troike 2015), which is unusual cross-linguistically. Determiner phrases with two layers of center-embedded relative clauses can be found, such as (9):

9.

pilam apšayš
people bad
 pinwakta
 things
 Dios pil'ta a-pa-tanko _
 God PRON commands
 tuče-t a-pa-hoy axam _
 DEM-3C 3-SUB-do NEG
tuče-x
DEM-3C
'The bad people, who do not do the things that God commands.'
(sub = subordinator; 3C = 3rd person concord)

pil'ta is an indefinite pronoun, and Troike (2015) suggests that its use in the innermost clause may be a means of mitigating the difficulty of the embedding. The role of pronouns, including indefinites, in facilitating processing of center-embedded clauses where they occur as subjects will be discussed further in Section 2 of this chapter regarding experimental evidence on English, and in Chapter 2 on corpus findings. In the bilingual text from which these sentences are sourced, the center-embedding in the Coahuilteco sentences contrasts with right-branching in their Spanish counterparts (e.g. 10), suggesting that center-embedding was normal in Coahuilteco and not an imposition of colonial Spanish writing styles:

10.

la gente mal-a,
DEF.FEM people bad-FEM
 que _ no haz-e las cosa-s,
 REL NEG do-3sg DEF.PL.FEM thing-PL
 que Dios mand-a _
 REL God command-3sg
'The bad people, who do not do the things that God commands.'

Another example demonstrates that Coahuilteco used extraposition to avoid a third level of center-embedding. In (11), [T_j] indicates what would be the non-extraposed position of clause j, *animas...yokwen* (Troike 2015):

11.

tawaxayo	Indulgencias	
all	indulgences	
	cin	
	1sg	
	[T _j]	
	na-pa-tox	
	1-SUB-earn	
tučen	nak-ax	in
DEM.1C	1.2-give	also
[animas		
souls		
	Purgatorio tukwet	a-p-sa
	Purgatory	dem.LOC-3C 3-SUB-be
tuči-yokwe-n]	j	
DEM-INSTR-1C		

'I also give you all of the indulgences that I have earned for the souls that are in purgatory'

In light of all this, it is evident that any claim about multiple center-embedding being avoided in all languages, in all circumstances, is exaggerated.

In addition, even languages which sometimes use syntactic modifications to prevent center-embedding may nonetheless allow embedding to some degree. Hawkins (1994: 8) also notes that SOV word order, as in Japanese and German, forces center-embedding of complement clauses more than does SVO order. While, as discussed in the previous section, word order flexibility allows clauses to be moved out of a center-embedded position such as by extraposition or scrambling, the center-embedded order is not always unacceptable. Hawkins (1994: 8) illustrates this phenomenon with the following examples from Japanese, which demonstrate how the same clause can either be center-embedded as in (12a) or preposed as in (12b):

12.

- a. Mary-ga [kinoo John-ga kekkonsi-ta to] it-ta
Mary-NOM [yesterday John-NOM marry-PST comp] say-PST
- b. [Kinoo John-ga kekkonsi-ta to] Mary-ga it-ta
[yesterday John-NOM married-PST comp] Mary-NOM say-PST
'Mary said that John got married yesterday'

He claims that sentences like (12a) are grammatical and acceptable in Japanese, whereas similar constructions in English (e.g. questions with center-embedded sentential NPs as in 8) are generally rejected by native speakers.

In the following sections, I will survey the factors that make center-embedding easier or more difficult in languages that have been studied, according to qualitative observations and experimental studies, and attesting found examples throughout to demonstrate how these factors are reflected in natural language outside an experimental setting. Furthermore, as I will discuss in a later section (1.4), some morphological factors in languages such as Japanese may contribute to a higher tolerance for center-embedding, and as will be discussed in Chapter 2, the prevalence of center-embedding in natural discourse is in fact higher in SOV languages than in those with predominantly SVO order.

1.2. Facilitating factors: English

Over the past six decades, many researchers have carried out experimental studies in attempts to disambiguate the extent to which center-embedding, specifically of clauses, is unacceptable in English, and which types and degrees of center-embedded constructions are acceptable. Other evidence comes from more impressionistic explorations of acceptability judgments and observed examples. It is evident that processability and acceptability of double center-embedded clauses in English is affected by a variety of syntactic, semantic, and processing factors that also influence sentence processing and acceptability in general, most related to the information content of the embedded clauses.

The next section (1.2.1) covers factors relating to the type of clause: complement vs. relative clauses (section 1.2.1.1.) and for relative clauses whether the relativized NP is the subject or object of its clause (1.2.1.2). Other factors concern the semantics of clause subject and predicate (1.2.2): referential form and specificity of sense of the subject noun phrases (1.2.2.1) and possibly the morphosyntax and semantics of the verbs (finiteness and lexical aspect; section 1.2.2.2.). In the case of both subjects and predicates, center-embedding appears more permissible if these components of the embedded clauses avoid introducing new referential information and/or carry less semantic detail. In addition, there are more global factors: prosody, which is influenced by the length of the clauses (1.2.3); and similarity-based interference (1.2.4). The data show that multiple center-embedding is not inherently unacceptable from a syntactic viewpoint, but is disfavored (in some cases) due to semantic and processing factors. While some languages may use either obligatory or optional word order modifications to avoid center-embedding, evidence from English – and elsewhere – suggests that center-embedding may not need to be avoided in all cases.

1.2.1. Type of embedded clause

1.2.1.1. Clause type: complements and relatives

Clausal center-embedding has often been presented as categorically difficult regardless of the type of clause involved, for example in Kimball's (1973) "principle of two sentences," which states that the parser cannot process components or more than two sentences at once. This would effectively rule out anything more than one level of center-embedding. However, both intuitive and experimental evidence on center-embeddings of different types of clauses show that some are easier to process than others. In particular, complement clauses seem to present less difficulty than relative clauses, and a complement clause containing a center-embedded relative clause is easier than the reverse configuration. The basis of these differences is the number and/or length of long distance dependencies, as explicated below.

Processing differences between relative and complement clauses, and different combinations thereof, were observed by Gibson & Thomas (1996), and explored in Gibson (1998). Specifically, sentences like (13a) are easier than (13b), although both feature the same types of clauses and two center-embeddings.

13.

a. Sentential complement, then relative clause:

C1 The fact
 C2 that the employee_a
 C3 who the manager hired _a
 C2 stole office supplies
 C1 worried the executive.

b. Relative clause, then sentential complement:

C1 #The executive _a
 C2 who the fact
 C3 that the employee stole office supplies
 C2 worried _a
 C1 hired the manager. (Gibson & Thomas, 1997a)

The contrast between these sentences presents problems for any analysis which takes all clausal center-embeddings to be equally difficult, such as Kimball (1973). Gibson & Thomas (1998: 37ff) explain the additional difficulty of the configuration in (1b) in terms of syntactic locality and memory cost. They note that a relative clause with a sentential complement embedded in it requires two long-distance dependencies to be held in memory: the subject-verb dependency of the relative clause in which the complement clause intervenes (“fact”... “worried” in C2), and the filler-gap dependency created by the relativized DP (“executive” and the “worried” object gap). Conversely, a sentential complement clause only requires one open dependency: between the head noun of the complement phrase (e.g. “fact”) and the verb of the main clause (“worried”). Therefore inserting a relative clause into a complement clause, as in (1a), only produces one long subject-verb dependency in the complement clause, and the two dependencies (subject/verb and filler/gap) in the relative clause are shorter than they would be if a complement clause was intervening (Figure 1.1)

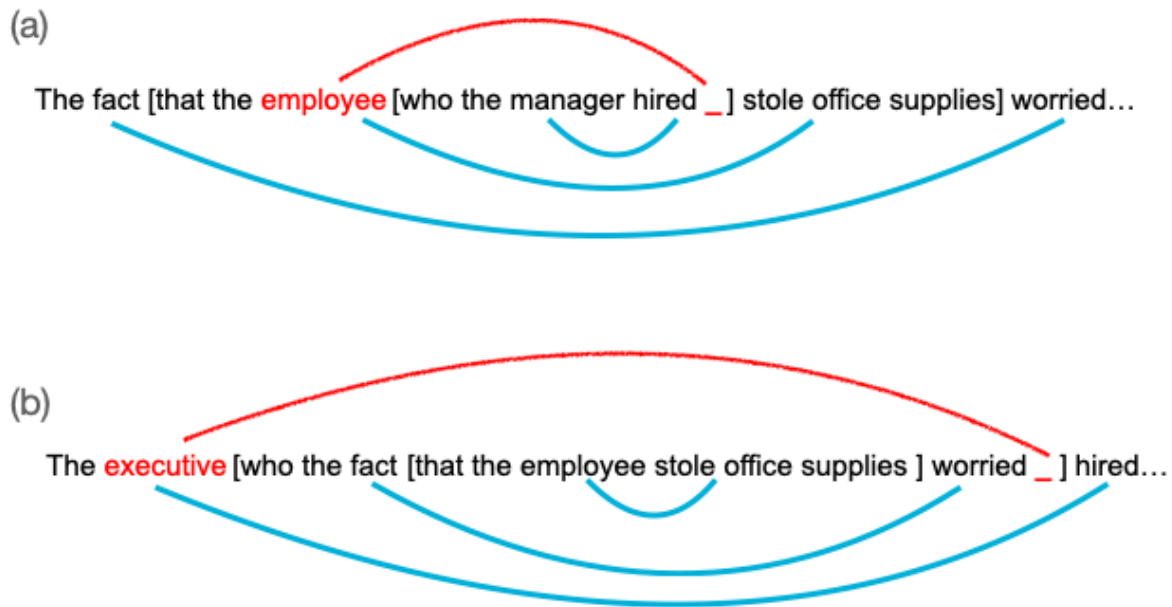


Figure 1.1: Dependency length comparison between a relative clause within a complement clause (a, top) and the reverse configuration (b, bottom), based on Gibson & Thomas (1998). Filler/gap dependencies are in red, subject-verb dependencies in blue.

As a result, total dependency length is shorter in (a) than in (b), even if both sentences contain clauses of the same type. An additional source of difficulty within these long dependencies, the introduction of new referents in embedded clauses, is discussed below in Section 1.2.2.1.1.3.

1.2.1.1.1: Found examples

Throughout the following sections I will discuss how attested examples of center-embedding tend to follow the criteria that have been determined, through experimental results and linguistic intuitions, to make them easier to process. While multiple clausal center-embedding is generally rare in natural language, examples have been observed (e.g. Karlsson 2007). The existence of naturally occurring center-embedding in various languages, as revealed through corpus searches, will be discussed more extensively in Chapter 2. These English examples (14 -15), of my own observation, display the configuration that Gibson and Thomas found to be relatively easy to process: a relative clause within a complement clause:

14.

[C1 The claim

[C2 that these SVO orders,

[C3 which are typical of so many inflectionally impoverished languages
and creoles,]

are simple]

is not readily defensible, therefore.] (Hawkins 2014: 38)

15.

[C1 The chances

[C2 that the persons

[C3 who are now being frozen]

will return to life]

are practically indistinguishable from nil.] (Hansson 2020)

Note also some similarities between the C3 clauses in these examples— specifically, they are subject RCs with a stative or passive predicate (“are typical,” “are being frozen”). The ways in which these properties of nouns and verbs facilitate processing will be elaborated in section 1.2.2. below. Most research on multiple clausal center-embedding has focused on the generally harder cases of a relative clause embedded within another relative clause, which I will now turn to, considering first the differences posed by types of relative clauses.

1.2.1.2. Clause type: Subject vs. object (and other) relative clauses

1.2.1.2.1. Relativization preferences: the accessibility hierarchy

The head noun of a relative clause may be extracted from various positions within its clause, but not all relativizations are equally acceptable. The insight that languages prefer some types of relative clauses over others goes back to Keenan & Comrie (1977), who described the Noun Phrase Accessibility Hierarchy (16). If a language can relativize a certain noun phrase type, it can also relativize all higher types in this implicational hierarchy:

16. Subject > object > indirect object > oblique > genitive > object of comparison

While the AH is a crosslinguistic typological phenomenon, it also has ramifications within languages regarding the acceptability and frequency of relative clause types, which reflect inherent cognitive constraints on relative clause formation (Keenan & Comrie 1977: 88ff). In English, subject relative clauses (like 17a) are generally preferred over object RCs (like 17b), by several metrics of comprehension and acceptability (Gibson 1998).

17.

- a. The reporter [who __ attacked the senator] admitted the error.
 - b. The reporter [who the senator attacked __] admitted the error.
- (King & Just 1991)

Subject relative clauses are more easily processed than object relative clauses, as shown by several different metrics; a useful overview of relevant findings is provided by Kwon et al. (2010). Compared to subject relative clauses, object relative clauses take longer to read (King & Just 1991, Lewis & Vasishth 2005: 393), are generally more difficult to process (Ford 1983, King & Kutas 1995, Traxler et al. 2002), are more difficult for children to acquire (Sheldon 1974, Tavakolian 1981, MacWhinney 1982: 111), and are more prone to comprehension errors (Larkin & Burns 1977, King & Just 1991, Gordon et al. 2001). Furthermore, object relatives are less frequent in corpora (Roland et al. 2007).

This discrepancy may be attributed to several factors. One possible explanation is the linear distance between the extracted filler word and the gap where it is interpreted (Gibson 1998, 2000), as shown in the above examples (17) where the filler is *the reporter*. Languages tend to minimize dependency length (Hawkins 1994, Futrell et al. 2015), as dependencies that go unresolved longer challenge working memory.

Linear distance between filler and gap is not a fully sufficient explanation for the increased difficulty of object relative clauses, since object relative clauses present the same processing challenges in Japanese (Miyamoto & Nakamura 2003) and Korean (Kwon 2008, Kwon et al. 2010), where their gaps are actually closer to the filler in linear distance. Therefore

the metric of distance involved must be phrase structure (hierarchical distance), not linear distance (see O'Grady 2011).

Another relevant factor (in English and other SVO languages) is the non-canonical word order in sentences with object relative clauses (Cooke et al. 2001): for example, (18b) begins with an OSV substring “the reporter (who) the senator attacked.” In addition, an object relative clause modifying the subject of a clause requires two switches of perspective (MacWhinney 2005). For example, in (18), the reader or listener’s perspective is initially focused on the subject (*the reporter*), but the following DP (*the senator*) forces a shift to itself; then, the verb *attacked* forces a switch back to the initial DP (*the reporter*), which is the verb’s object (MacWhinney 2005: 209). A sentence with two center-embedded object relative clauses would therefore require four perspective-switches (MacWhinney 2005: 210).

1.2.1.2.2. Subject vs. object relative clauses in center-embedding

Several studies have directly compared the comprehensibility and acceptability of subject and object relative clauses in multiple center-embedding. Gibson et al. (1995) reported that object relative clauses were evaluated as slightly but significantly more difficult than subject RCs, whereas Hudson (1996: 11) claimed that the effect is stronger, based on a small-scale memory study in which participants were asked to write down a sentence (all sentences being equal in length) immediately after hearing it. In his stimuli for this question, Hudson varied only the form of the deepest-embedded clause, designated here as C3. It was confirmed that sentences like (18a), with a subject relative C3, are easier to remember than those with object relatives like (18b), which almost all participants remembered incorrectly:

18.

- a. [C1 The farmer_a
 [C2 the cow_b
 [C3 that___b gave bad milk]
 kicked ___a]
died.

- b. [C1 Beer_a
 [C2 students_b
 [C3 policemen follow __b]
 buy __a]
 comes from very many different places.

Hudson (1996: 11) also notes that (19), presented in Sampson (1996) as a counterexample to the claim that center-embedding is particularly difficult or rare, features a subject relative clause as its deepest clause (C3):

19.

- [C1 The only thing_a
 [C2 that the words_b
 [C3 that __b can lose -*d*]
 have in common __a]
 is, apparently, that they are all quite common words.]

Gibson & Thomas (1996) found comparable results in an acceptability questionnaire: when C3 was a subject relative clause (as in 19a), the result was more acceptable than two nested object relative clauses (as in 19b). Other reading time experiments and computational simulations (McElree et al. 2003, Lewis & Vasishth 2005), show that clauses with two center-embedded object relative clauses are harder to process than other configurations, such as a subject relative inside an object relative. McElree et al. (2003) assessed the difficulty of different embedding structures using a reading time/sentence decision task where subjects were asked to evaluate whether a sentence was acceptable after reading it word by word. Errors were highest and response times longest in the two-object-RC condition. Lewis & Vasishth (2005: 406) confirmed through computational modeling that doubly nested object relative clauses are particularly likely to cause parsing failure.

In a survey of over 100 found examples of center-embedding across texts in several European languages, Karlsson (2007) found that sentences with an object relative clause inside another object relative clause did not occur. However, this observation does not mean that such sentences are not processable or acceptable, as will be shown below.

Based on these observations, it appears that (all else being equal) subject relatives embedded in object relative clauses are tolerated in normal English discourse and writing, even if doubly embedded object relatives (the paradigmatic example of problematic center-embedding) present difficulties. However, there is another factor at work: it can be observed that in Hudson's unacceptable example, for instance, all three noun phrases are bare plurals. (This morphological similarity, in itself, along with the semantic similarity of "students" and "police", is likely itself a contributing factor to processing difficulty. I will elaborate on the role of similarity in section 1.2.4). The referential form and specificity of noun phrases are also significant factors in the acceptability of center-embedding, as I will show more fully in the following section.

1.2.2. Subject and predicate factors

1.2.2.1. NP/DP semantics: specificity of reference and sense

Another factor impacting sentence processing, and center-embedding in particular, is the semantic content of noun/determiner phrases. The meaning of a noun phrase can be divided into two elements: reference and sense. *Reference* (or *referent*) denotes the particular individual entity which the noun phrase refers to, while *sense* refers to its expressive meaning – as defined by Lycan (2018: 32), "the sense reflects a person's conception or way of thinking of the referent". In Frege's classic example (Frege 1948), *Morning Star* and *Evening Star* have the same reference (the planet Venus), but not the same sense. Reference and sense can both be more or less specific, and this specificity affects sentence processing. Center-embedded sentences become easier to process, in general, if the subject noun of the main clause is relatively specific, and the subject nouns of the embedded clauses, especially C3, less specific. This is because more specific noun phrases (while incurring a greater processing cost at initial encoding) are easier to retrieve from memory at a subsequent gap (Hofmeister 2011), and because, as discussed below, noun phrases with less semantic content interfere less with

processing (in this case, maintenance of an earlier filler in working memory) than those which introduce new referents. In the following sections I will address the effects of both dimensions of specificity: reference and sense.

1.2.2.1.1. Referential specificity

One syntactic factor that is known to affect the grammaticality of WH-movement in general, and that of center-embedded relative clauses in particular, is what Marslen-Wilson et al. (1982) call the lexical specificity of the noun phrases involved. I will follow Kluender (1992, 1998) in calling this concept *referential specificity*. Different types of noun phrases may be ranked by this criterion of specificity: proper names (*Garfield*) and definite descriptions (*the orange cat*) are the most specific, indefinite common nouns (*a cat, cats*) less so, and pronouns least of all (Ariel 1989, 2001, Gundel et al. 1993, Marslen-Wilson et al. 1982), as their referents are determined by linguistic and/or real-world context.

1.2.2.1.1.1. Categorizing referential specificity

The insight that discourse familiarity determines NP form goes back (at least to) Karttunen (1976) and led to the framework termed *file change semantics* by Heim (1982, 2002). In this theory, when a new discourse referent is introduced – usually by an indefinite noun phrase – interlocutors create a mental “file card” for it which is updated as new information is added. Once a referent has been added to the discourse, it can be referred to with a definite DP or a pronoun, and interlocutors’ file cards for this referent are updated with each new mention to add new information as needed, as described by Erteschik-Shir (1997: 4). Indefinites generally introduce new “cards,” while definites pick out existing “cards” (Erteschik-Shir 2007: 52-3), and referents referred to by focused NPs can subsequently be referred to with pronouns.

Drawing on this line of research, Ariel (1989, 2001, 2014) distinguishes a continuum of referentiality (the degree to which a noun has a specific referent) determined by pragmatics: the referentiality of a noun phrase depends on how accessible the referent is in discourse (or in file

change terms, how accessible its file is), and types of noun phrases can be ranked in this respect. A speaker's choice of accessibility marker acts as a cue to the listener on how to retrieve the appropriate mental representation – proper names and definite descriptions, for example, must be retrieved from general world knowledge, whereas the referents of forms like pronouns can be retrieved from linguistic context or immediate physical context. Ariel's full scale of noun phrase types is reproduced here as (20):

20.

Accessibility scale of noun phrase types from Ariel (2014: 73):

Low Accessibility

1. Full name + modifier
2. Full "namey" name
3. Long definite description
4. Short definite description
5. Last name
6. First name
7. Distal demonstrative + modifier
8. Proximal demonstrative + modifier
9. Distal demonstrative (+ NP)
10. Proximal demonstrative (+ NP)
11. Stressed pronoun + gesture
12. Stressed pronoun
13. Unstressed pronoun
14. Clitic pronoun
15. Gap or zero

High Accessibility

Pronouns and zero anaphora are used for the most accessible discourse referents, including the participants (which are referred to with indexical pronouns such as *I* and *you*), while definite noun phrases such as *the friend* may be used for those that are less accessible (Ariel 2001: 29). First names are intermediate in accessibility, less accessible than pronouns, but more so than either definite descriptions or full names, as they convey familiarity with the referent (Ariel 1989: 74, Ariel 2014: 40). Generally, lower accessibility markers are preferred initially in a conversational turn when a new referent is introduced, while higher accessibility markers occur later (Ariel 2001: 32). Similarly, Marslen-Wilson et al. (1982) found that names and definite

descriptions are used more heavily at the beginning of a narrative or a scene within a narrative (after a transition), but pronouns (and zero anaphors) are used more frequently later, when the characters in the narrative are well-established. The relevance to center-embedding of zero anaphors, which are the very highest accessibility category, will be discussed in the subsequent section on non-finite verbal forms, which allow the subject noun phrase of an embedded clause to be simply dropped.

Another approach to the discourse function of noun phrase form is the givenness hierarchy of Gundel et al. (1993), an implicational hierarchy wherein the form of an NP or DP is determined by how identifiable it is to the participants in a discourse. Identifiability is measured along the scale shown in Table 1.1, in which each status entails all statuses to its right (e.g. nouns which are familiar are also uniquely identifiable, referential, and type identifiable):

Table 1.1: Givenness Hierarchy and typical forms of reference, from Gundel et al. 1993.

in-focus	activated	familiar	Uniquely identifiable	referential	Type identifiable
<i>it</i>	<i>this /that /this N</i>	<i>that N</i>	<i>the N</i>	indefinite <i>this N</i>	<i>a N</i>

Position on this hierarchy determines the choice of noun phrase form; for example, in-focus referents (central to the discourse) are typically referred to with pronouns; uniquely identifiable but non-focused referents with definite descriptions; and type identifiable referents (the least identifiable and most peripheral to the discourse) with indefinite nouns. Indefinite nouns and their associated referents are not discussed specifically by Ariel (2001, 2014), but in the analysis of Gundel et al. they are less identifiable than what Ariel designates as low accessibility markers, i.e. proper names and definite descriptions.

1.2.2.1.1.2. Referential specificity and center-embedding: qualitative observations

Examination of the examples we have discussed so far suggests that the referential specificity of a noun phrase affects the well-formedness of center-embedding – e.g., one of Hudson’s problematic examples (3b) featured two bare plurals in C2 and C3 (which are also semantically similar): *students* and *policemen* as subject noun phrases. Several studies have directly tackled questions of this type, comparing the difficulty of center-embedded sentences with subject types corresponding to different levels on the scales of Ariel and Gundel, although not all approach the topic through an explicit framework of accessibility or givenness. As I will show below, it is evident that the more discourse-available the noun phrases in a sentence are – i.e., the higher it occurs on Ariel’s scale of accessibility, or on Gundel’s scale of givenness – the more acceptable center-embedding becomes, even for otherwise difficult object relative clause embeddings.

Relatedly, Niv (1993) proposed a general “avoid new subjects” principle in sentence processing which applies particularly when the subject is a noun phrase with low accessibility in the discourse, i.e. one introducing a new referent. He also applied this observation to center-embedded sentences, contrasting the contrived example (21a) with a processable sentence (21b):

- 21.
- a. The rat_a
 [C1 that the cat_b
 [C2 that the dog bit _b]
 chased _a]
died.
 - b. [C1 A book_a
 [C2 that some Italian _b
 [C3 I’ve never heard of _b]
 wrote _a]
will be published soon by MIT press. (Frank 1992: 278)

(8a), a “classical” example of difficult center-embedding, requires three definite subject DPs to be introduced and processed in sequence and then matched in last-in-first-out order to their

verb phrases. (8b), however, has an indexical pronoun as its C3 subject. Furthermore, the C2 subject *some Italian* is a quantified expression that does not introduce a new discourse referent, but rather indicates a person whose exact identity is not known or relevant; the role of indefiniteness will be discussed further in the following subsection on specificity of sense.

Kluender (1998: 248) independently arrived at the same observation, which he illustrated with the following minimal pair of sentences. (22b), with an indefinite pronoun in C1 and an indexical pronoun in C2, is easier to process than (22a), which has definite description DPs of identical structure in all of its clauses:

22.

- a. [C1 The woman_a
 [C2 the man_b
 [C3 the host knew __b]
 brought __a]
 left.
- b. [C1 The woman_a
 [C2 someone_b
 [C3 I knew __b]
 brought __a]
 left.

This observation was originally due to Bever (1970). Early in the history of psycholinguistics, it was shown that the processing difficulty of center-embedding is mitigated by manipulating the referential form of the subject of C2 (the most deeply embedded clause in a two-level embedding). Since quantifiers like *someone* and indexical (first/second person) pronouns do not introduce a new discourse referent, they do not overload processing to the same degree as do “full” noun phrases. Bever (1974: 189) observed that quantifiers as well as pronouns make center-embedding more processable, and also showed that the facilitating effect could work at deeper levels of embedding, such as (23). He states that “many listeners” find (23)’s triple-embedding of object relative clauses acceptable because of the variation in its subject noun phrases.

23.

[C1 The pictures _a
[C2 a reporter _b
[C3 everyone _c
[C4 I met _c]
trusts _b]
took _a]
showed that arson caused the fire.

The C2 subject of (23) is low accessibility: *a reporter* is an indefinite (type identifiable, in Gundel's terms), so it introduces a new referent. (However, the difference in definiteness between "the pictures" and "a reporter" may decrease interference; see section 1.2.4 for more on this phenomenon.) Furthermore, *everyone* is a quantifier (i.e. not referential), and the subject of C3 is an indexical pronoun. Thus, the two most deeply nested subject noun phrases do not introduce new discourse referents, making what would otherwise be a very complex construction comprehensible, at least to some listeners. For others, the level of embedding nonetheless makes the sentence hard to process despite the ameliorative choice of noun phrases.

In one of his small-scale memory experiments, Hudson (1996:15) drew on the insights of Niv and Bever concerning noun phrase referentiality. He showed that first names induce ameliorative effects similar to those of indexical pronouns in center-embedded contexts (cf. Ariel 1989: 74); participants were more capable of retaining the sentence in short-term memory. Hudson found that sentences like (24a) and (b) were much less likely to be misremembered than sentences like (24c), where C3 has an bare plural as subject:

24.

a. [C1 The shells _a
[C2 that the children _b
[C3 we watched _b]
collected _a]
were piled up.

- b. [C1 The apples _a
 [C2 that the girls _b
 [C3 Bill watched _ _b]
 collected _ _a]
 were heaped up.
- c. [C1 People _a
 [C2 that politicians _b
 [C3 who journalists interview _ _b]
 criticise _ _a]
 can't defend themselves well.

It is easier to relativize an argument from an embedded clause C3 with an indexical pronoun subject (24a) than one with a bare plural subject (24c) because the pronoun's referent is given from the speech situation and therefore the pronoun is not perceived as introducing a new discourse referent, as predicted in Ariel's and Gundel's models. Therefore one source of processing difficulty is reduced (for a more detailed formal analysis, see Section 1.2.2.1.1.3. below). An additional likely factor in the difficulty of (24c), and Hudson's other bare plural examples, is similarity-based interference, as will be discussed regarding English in a subsequent section, 1.2.4. – in this case, (24c) contains a bare plural subject in each of its three clauses. The relative processability of (24b) suggests that first names produce ameliorative effects similar to those of indexicals. Hudson (1996: 15-16) suggests that “common nouns” (he does not specify bare plurals, although those were the specific types of NP that appeared in his difficult stimuli) as subjects of C3 are particularly problematic for processing in center-embedded sentences.

It has been assumed so far that bare plurals like *people* and *journalists* have low discourse accessibility, but this may not always be the case, and different interpretations of the same morphological form may have different implications for processability. The example given here as (24c) features the bare plural NP *journalists*, which under Gundel et al.'s (1993) analysis of givenness would be the least “available” type of NP in discourse because it is indefinite. However, this analysis of bare plurals may not hold in all cases, since they do not always

introduce new referents. Bare plurals may function more like quantifiers in sentences like (25b) rather than adding a new referent (some group of journalists) as in (25a):

25.

- a. Journalists arrived at the White House.
- b. Journalists are dishonest.

If bare plurals in sentences like (b) can be analyzed similarly to quantifiers (in this case a universal quantifier over the set of journalists), they would be expected to facilitate processing of center-embedded sentences when they appeared in C2 or C3, whereas those introducing new referents would add difficulty in the same position. However, this distinction has not been explicitly addressed with regard to center-embedding. I return to the issue of bare plurals in Chapter 2, Section 2.4.2.1, with regard to observed English examples of center-embedding.

1.2.2.1.1.3. Formal analyses and experimental results

Thus far we have observed the effects of quantified expressions and indexicals on the acceptability of center-embedded structures. However, these have been based on intuitive judgements or informal experiments. We now turn to more rigorous analyses and experimental results on how the processing of multiple center-embedding may be facilitated by variation in noun phrase specificity.

As previously discussed, the difficulty of center-embedding is proposed to stem from dependency length, and the problem of keeping multiple dependencies open at once; Gibson (1998, 2000) created models to formalize this insight. On this view, the processing load is exacerbated if a new discourse referent is introduced in the middle of such an unresolved dependency (Gibson 2000). Filler-gap or subject-verb dependencies crossing definite descriptions would be particularly difficult, as a definite description DP usually serves to introduce a new referent (at least in sentences presented alone without supporting context, as in many processing experiments). In the terms used by Gibson (2000: 104), the integration cost of

verbs increases with the number of new discourse referents that have been introduced between the subject and the verb, such as in a center-embedded clause. A structure with two or more center-embedded object relative clauses, where the clauses have specific subject noun phrases, becomes difficult because multiple such intervening referents occur (Gibson 2000: 106).

In (26), adapted from Gibson (2000), I have marked the integration cost at each phrasal head.

26.

a.

The reporter (0)
 who the senator (0)
 who the professor (0) met (1) _
 attacked (7) _
disliked (7) the editor.

b.

The reporter (0)
 who the senator (0)
 who I (0) met (1) _
 attacked (5) _
disliked (5) the editor.

In (26a), cost spikes at the verb *attacked* because of several incurred costs: first creating the event structure for the verb (cost 1), then integrating it with the subject *senator* (separated by two intervening discourse referents and thus adding a cost of 2), and finally integrating the gap as object. In this last step, four intervening discourse referents – *senator*, *professor*, *met*, and *attacked* itself – occur between the gap and its filler *senator* (cost = 4, for a total cost of 7). The integration of *disliked* is similarly complex. In contrast, the integration cost in (26b) is lower because the pronoun *I* is not introducing a new referent, so the integration costs for the verbs *attacked* and *disliked* are decreased by two (one at the subject integration and the second at filler-gap integration).

While Hudson's experiments were small-scale and informal, more detailed and quantitative experiments have also been conducted to test the predictions of Gibson's (2000)' model, along with hierarchies of referentiality. Warren & Gibson (2002) performed experiments measuring participants' subjective ratings of comprehension as well as their reading times. With these experiments, they set out to test more explicitly the relationship between referentiality and center-embedding with a wider range of referential forms than Hudson used.

1.2.2.1.1.3.1. Warren & Gibson (2002), Experiments 1 and 4: Subjects of C3

The first experiment performed by Warren & Gibson (2002) compared doubly center-embedded (object relative clause) sentences with four types of noun phrases at the C3 clause subject position: indexical (first or second person) pronouns, third-person pronouns (with no eligible antecedent in the clause itself), short proper names, and definite descriptions. (27) shows all the conditions in C3:

27.

[C1 The student _a
 [C2 who the professor _b
 [C3 who {I/they/Jen/the scientist} collaborated with _b]
 had advised _a]
 copied the article.

It was found that when the subject of the deepest clause C3 was an indexical first or second person pronoun, the sentence was rated as significantly more comprehensible than with all the other types of noun phrases, which did not differ significantly from each other (Warren & Gibson 2002: 85). The difficulty of all third-person NPs, including pronouns, may be attributed to the introduction of a new discourse referent (the pronoun "they" was chosen to have no available antecedent, whereas first or second-person pronouns always refer to discourse participants). Moreover, the difficulty of introducing a new discourse referent is worsened at the most deeply embedded clause (C3), where the new subject interrupts two long-distance dependencies, as shown above in (27). A further experiment (Experiment 4 in Warren & Gibson 2002) found

comparable effects of givenness on reading time; i.e. center-embedded relative clauses with a definite description subject took longer to read than those with indexical pronouns, and comprehension of these sentences was also poorer.

1.2.2.1.1.3.2. Warren & Gibson (2002), Experiments 2 and 5: Givenness of subjects

Warren & Gibson's (2002) second experiment was based on the givenness hierarchy of Gundel et al. (1993), and contrasted center-embedded and right-branching sentences with the following types of subject noun phrases in the most deeply embedded clause: indexical, third-person pronoun, first name, famous name (which they predicted should be easily accessible to subjects), definite description, and indefinite. In (28), the alternate noun phrases are shown in givenness hierarchy order from in-focus (indexical pronouns), to type-identifiable (indefinite). In sentences using the third person pronoun, the sentence was prefaced with a clause such as "According to Brad," to provide a discourse antecedent for the pronoun.

28.

[C1 The old lady
[C2 who the government assistance program
[C3 which {you, he, Brad, Bill Clinton, the reporter, a reporter} praised _]
had saved _]
did not have enough money to heat her house.

It was found that the lower the C3 subject was on the Givenness Hierarchy, the higher the difficulty rating for center-embedded sentences, and this monotonic trend accounted for a significant amount of the variance in difficulty – although no comparable effect was evident with right-branching sentences. The indefinite condition was slightly, but not significantly, more difficult than the definite description condition (Warren & Gibson 2002: 90).

In a follow-up (Experiment 5 in their paper), Warren & Gibson (2002: 99) measured the effect of the same subject factors on reading time. Self-paced reading times were compared for center-embedded object relative clauses with the following types of subject noun phrases: indexical pronouns, famous names (such as *Donald Trump*), definite descriptions, and

indefinites. They found that reading time was affected by subject type, such that indexical pronouns had a significantly shorter reading time than indefinites, and the other types of subjects fell in between (Warren & Gibson 2002:101-2). These experiments, taken together, demonstrate how the increased processing difficulty of more referential NPs manifests in different measures.

1.2.2.1.1.3.3. Warren & Gibson (2002), Experiment 3: Referential form and clause depth

Another experiment (Warren & Gibson 2002: 91-4) showed that center-embedded sentences with quantifiers such as *everyone* in C3 are rated as more comprehensible than those with a definite noun phrase as C3 subject and a quantifier in the higher clause C2. These in turn are more acceptable than sentences with a quantifier as the main clause C1 subject and two embedded clauses featuring referential noun phrases. In other words, the facilitating effect of the quantifier increases when it occurs in a more deeply embedded clause. These results demonstrate that Bever's (1970) insights about how variation in noun phrase form facilitates comprehension (see section 1.2.2.1.1.2.), while accurate, do not completely capture the effect of quantifiers on center-embedding. Since the effects of replacing a noun phrase with a quantifier are greater at C3, it is evident that C3 is a cause of particular difficulty, a result in line with Gibson's (2000) analysis of integration cost. Definite noun phrases appear to interfere with the already challenging task of keeping multiple open dependencies in memory.

The effect of proper names as subjects of C3 is complex and the experimental results were varied, and not necessarily consistent with Ariel's theory of accessibility. If names are considered as rigid designators (Kripke 1980; for further discussion see LaPorte 2018) with one fixed referent, they should be low accessibility. This is what Ariel (2014) postulates for full names. However, as Ariel (2014: 44) suggests, first names are higher accessibility than full names, and create a sense of familiarity. Experimental evidence suggests that first names may behave more like pronouns than nouns in facilitating relative clause processing. Hudson (1996)

found that center-embedded sentences with proper (first) name subjects in C3 are about as easy to remember accurately as those with pronoun subjects at the same position, whereas Warren & Gibson's (2002) more refined analysis suggests that first names are slightly more difficult than pronouns. It seems that first names, in this case, are treated by hearers as similar to third-person pronouns with no specific antecedent, and thus no need to retrieve real world knowledge, as is the case for low accessibility proper names and definite descriptions.

Famous names, on the other hand, with a specific real-world referent, seem to function more like definite descriptions: Warren & Gibson (2002) found that they were intermediate between first names and definite descriptions in processing difficulty. Ariel (2014) presents full names as the lowest accessibility type of noun phrase, but names of well-known individuals may be more accessible, as suggested by Warren & Gibson's results. Taken together, these results imply that common nouns make center-embedding more difficult than proper names, which in turn are more difficult than 3rd person pronouns, and first and second person pronouns are the easiest of all (see also Ariel 2014: 47-8). Quantifiers also appear to create ameliorative effects similar to pronouns (cf. Bever 1974 and Warren & Gibson 2002).

1.2.2.1.2. Specificity of sense (lexical semantic complexity)

1.2.2.1.2.1. Overview of sense specificity

There is ample evidence, as discussed above, that the discourse accessibility or givenness of noun phrases affects the acceptability of center-embedding, with definite and indefinite common noun phrases being most difficult to process. However, nouns within this low-accessibility category vary in their lexical specificity. Hofmeister (2011: 380) calls this concept "semantic complexity" and offers the following definition:

For two descriptions, x_1 and x_2 , denoting a discourse entity e , if the semantic and syntactic feature-value pairs encoded by x_2 are a proper subset of the feature-value pairs encoded by x_1 , then x_1 is more complex than x_2 .

For instance, the noun *building* is a hypernym denoting a general category of object which has more specific hyponyms such as *house*, *store*, *school*, etc. (Carter 2012: 35), and each hyponym has semantic features that the general category noun does not. Even less specific are vague words such as *thing(s)* and *stuff*, which are nonspecific in meaning and used to refer to (what speakers assume is) part of shared knowledge or experience (Overstreet 1999: 65, Evison et al. 2007). Bresnan (1973: 271) describes these semantically vague words as “semi-pronouns”. Consequently, it makes sense to categorize words like *stuff* as higher accessibility than more specific noun phrases, since their meaning is determined by discourse and/or pragmatic context and they do not introduce new specific referents. I will refer to this parameter as “specificity of sense,” and nouns with low specificity as “vague¹.”

1.2.2.1.2.2. Possible relevance to processing and center-embedding

There is also evidence that the sense specificity of a noun may influence processing difficulty: Hofmeister (2011) showed that in relative clauses, head nouns with a more specific sense (e.g. *soldier*) cause a slight slowdown in reading time upon introduction into the discourse relative to their hypernyms (e.g. *person*) even if they are phonologically similar. However, specificity of sense also facilitated filler-gap processing at a later point within the relative clause: reading times at gap positions, where noun phrases were presumably retrieved from memory, decreased with more specific head nouns.

In light of Hofmeister (2011), the considerable difficulty of Hudson’s (1996) examples with bare plurals could be influenced by another factor: his example (12c) above, reproduced here as (29a), has the semantically complex (i.e. sense-specific) C3 subject noun *journalists*, while the main clause subject noun was the vague noun *people*. This would make C3 harder to process, and additionally, *people* would incur more processing costs to retrieve at the gap than

¹ I am using “vague” here only in the sense used by Overstreet (1999) and Evison (2007), which differs from its general usage in semantics and philosophy, where a vague predicate is one which admits borderline cases (Sorensen 2022).

would a specific hyponym. The variant (29b), with the vaguer noun in C3 and the more specific one as main clause C1 subject, seems easier in my judgment:

29.

- a. [C1 People
 [C2 that politicians
 [C3 who journalists interview _]
 criticise _]
 can't defend themselves well.
- b. [C1 Journalists
 [C2 that politicians
 [C3 who people interview _]
 criticise _]
 can't defend themselves well.

These findings also fit with those of Warren & Gibson (2002) concerning the facilitative placement of quantifiers in center-embedded sentences: the most processable sentences have a specific noun phrase as main clause C1 subject – facilitating processing at the gap following the center-embedded clauses – and a quantifier as the C3 subject, which simplifies C3 by avoiding a new referent.

The effect of sense specificity on multiple center-embedding has not been explicitly studied. Hudson (1996) performed some experiments that are relevant (as discussed in the preceding paragraph for (12)), but he did not overtly raise the question. Gordon (2004: 106) investigated the effect of vague versus specific nouns (e.g. *person* vs. *salesman*) on the comprehension of object relative clauses, and found no significant effect. However, based on the general effects of givenness and referential form on sentence processing, it seems plausible that semantic vagueness could likewise facilitate center-embedding.

1.2.2.1.3. Found/attested examples relevant to subject specificity

Other evidence for the role of noun semantics (both referential and sense specificity) in the comprehensibility of center-embedding comes from some of the found utterances cited as

counterexamples to the general claim that two-level center-embedding is inherently difficult to process. De Roeck (1982: 332) reports slipping (30), which has two center-embedded object relative clauses, into a discussion about sentence processing:

30.

Isn't it true that
 [C1 sentences
 [C2 that people
 [C3 you know _]
 produce _]
are more likely to be accepted?

Interlocutors did not seem to find this sentence difficult or unusual, according to De Roeck, despite the fact that they had just listened to a seminar in which similar structures were highlighted as difficult or impossible to process. However, this sentence differs from the usual center-embedding examples in an important way: its noun phrases vary in referential form and the subject of C3, importantly, is an indexical pronoun. In addition, the main and C2 clause subjects are bare plurals. The C2 subject *people* is what Gundel et al. (1993) would classify as a low-givenness and low-identifiability noun. However, it is a “vague” noun in the sense used by Evison (2007): its lack of specificity means that it is not introducing a difficult-to-access new discourse referent (so it is functionally more like a quantifier such as *someone* or *everyone*).

Another found example is particularly relevant to the issue of sense specificity. Labov (1973: 102) reported on an informal experiment in which (31), with a relative clause center-embedded inside the complement clause of “report,” was introduced into casual conversation:

31.

Do you think
 [C1 that the report
 [C2 that the stuff
 [C3 they put in diet soda _]
 causes cancer]
is a hoax?]

Listeners did not regard this sentence as ungrammatical or hard to comprehend, or even seem to notice anything odd. The sentence features the vague noun *stuff* as subject in its C2; as explained above, nouns like this do not introduce new discourse referents, but refer to assumed shared knowledge (Overstreet 1999: 99ff, 146). In this case, *the stuff* presumably refers to a food additive known to the interlocutors and suspected to be toxic. The subject of C3 is also a nonspecific *they*, which can be interpreted as referring to the unspecified manufacturers of diet soda. As discussed above, the configuration of a relative clause inside a complement clause is a relatively easy form of center-embedding, but in Labov's sentence processing is further facilitated by the choice of subject noun phrases.

Therefore, while sentences like this stand as counterexamples to any claim that multiple center-embedding is inherently unprocessable (based largely on contrived examples with definite description clausal subjects), they do not challenge such claims as Hudson's (1996: 15) suggestion that common nouns are particularly problematic for processing of center-embedding when they occur in the most deeply embedded clause. The features seen in these sentences are also consistent with those found to be more processable, comprehensible, and/or acceptable in formal experiments: i.e. less referentially specific subjects in embedded clauses.

In general, sentences with two center-embedded clauses are more acceptable when the subjects of the embedded clauses (C2 and C3) are high-accessibility, i.e. they lack referential specificity. This general trend is supported by qualitative intuitions, experimental results, and observations of natural examples. Nouns that are less semantically detailed (i.e. are lacking specificity of sense) may also contribute to acceptability of center-embedding when they occur in embedded clause subjects, although there is less concrete experimental evidence concerning this parameter.

1.2.2.2. Predicate factors: Verb inflection and lexical aspect

We have previously observed (1.2.2.1) that sentences with two layers of clausal center embedding (particularly when both are relative clauses), are easier to process with less specific NPs as subject of C3; specificity may involve either reference or sense. There is some evidence that comparable effects may occur when verbs carry less information, whether because they lack tense marking or because their lexical aspects are semantically simpler. For example, if the C3 clause verb is a participle (as in 32b) or infinitive rather than a finite verb (as in 32a), then the sentence becomes more processable and acceptable.

32.

a.

The school board
 which the teachers
 who were neglecting the students
 had angered
troubled the superintendent.

b.

The school board
 which the teachers
 neglecting the students
 had angered
troubled the superintendent.

Not only do nonfinite verbs allow the clause subject to be dropped (itself a major facilitating factor), they may carry less referential information than finite verbs by virtue of not having tense marking (Partee 1984). The concept of tense as a referential element, and its possible impact on center-embedding, is surveyed in subsection 1.2.2.2.1. The lexical semantics of verbs (subsection 1.2.2.2.2) may also influence the acceptability of center-embedding – for example, verbs can be understood as more or less semantically complex depending on their Aktionsart or lexical aspect, with less semantically complex verbs plausibly being more permissive of embedding, although experimental confirmation is so far lacking.

1.2.2.2.1. Finiteness

1.2.2.2.1.1. Tense as a referential element

The salient feature shared by the noun phrase factors discussed in the previous section (1.2.2.1) can be characterized as follows: the less specific the NP in either reference or sense, the more acceptable and processable it renders a center-embedded clause. It is possible that similar considerations apply to verb tense marking, although evidence is sparse.

As discussed by Partee (1973, 1984) tense can be considered to be a referential element, like a pronoun, but in the verbal system. For example, verb tenses are like pronouns in that they may be deictic (referring to a specific real-world time) or anaphoric (referring back to a time mentioned earlier in the sentence). As Partee (1984: 256) also notes, a sentence with a past tense verb must be interpreted with respect to a reference time, although tense markers do not strictly “refer” to this time as pronouns do to individuals (see also Webber 1998). If tenses can be considered in some sense referential, then they might under certain circumstances be understood to cause the same sort of processing load as noun phrases that introduce new referents (what Ariel would call “low-accessibility”; see subsection 1.2.2.1.1.1 for more on this concept and its relevance to center-embedding).

1.2.2.2.1.2. Nonfinite verbs and center-embedding

There is some evidence to the effect that absence of tense marking on the verb in C3 can influence the acceptability of a center-embedded sentence, although it is not clear how this factor might be disentangled from other observed facilitating factors. Hudson (1996) found that (33), with a past passive participle *hired* in a reduced subject relative clause C3, was relatively easy to remember correctly, compared to sentences with finite verbs at the same position:

33.
[C1 People_a
 [C2 that footballers_b
 [C3 _b hired by managers]
 attack _a]
get plenty of excitement.]

There are several reasons why the participle is easier to process. For one, the difficulties of an object relative clause (which would be “footballers [managers hire __]”) are avoided by passivization.² Also, in the C3 clause “hired by managers,” there is no overt subject NP; as we have previously seen, decreasing the referential specificity of the C3 subject NP makes difficult center-embeddings more processable, so it is to be expected that eliminating the subject altogether would streamline processing further.

The lack of a (referential) tense marker may be a facilitating factor in itself. Hudson (1996:10) notes that examples like (34) seem to be quite easy to process, for center-embeddings:

34.

[C1 Books_a
 [C2 that people_b
 [C3 ___b studying linguistics]
 buy ___a]
 are expensive.]

In this case, C3 is a non-finite subject relative clause and the subject of C3 is a zero anaphor, coindexed with C2’s subject *people*; as discussed by Ariel (2014), zero morphs are the highest accessibility markers, and therefore they should be expected to considerably facilitate processing at C3, since they refer back to an established referent rather than introducing a new one. This result is consistent with two previously discussed observations: the greater ease of processing subject relative clauses (1.2.1.1.), and the correlation of processing difficulty with the lexical specificity and semantic richness of the C3 subject noun phrase. This effect of verb non-finiteness (present and past participles) offers more evidence that center-embedded constructions become more acceptable/processable the fewer referential elements (or the less

² Keenan and Comrie (1977) observed that languages which do not permit relativization of direct objects may convert them into subjects, e.g. through passivization, to allow them to be relativized. While relativization of direct objects is grammatical in English, it presents more processing difficulties than subject relative clauses, as discussed previously (section 1.2.1.2.) .

information) C3 contains. This “easy” example becomes slightly harder, to my perception, if the verb of C3 is made finite (35):

35.

[C1 Books_a
[C2 that people_b
[C3 who_b study linguistics]
buy _a]
are expensive.]

This subjective observation is backed up by more detailed experimental support. Gibson (1998) reported on a complexity rating questionnaire that explicitly compared center- embeddings with tensed and untensed C3 clauses (36); the latter, omitting the bracketed “who were”, were rated by participants as less complex.³

36.

The school board
which the teachers
[who were] neglecting the students
had angered
troubled the superintendent.

The tensed verb “be” in “were neglecting” itself constitutes a discourse referent along with the NPs “the teachers” and “the students” (Gibson 1998: 37), so it adds to the difficulty of processing.

In this connection, it is also informative to look back at paradigmatic center-embeddings of the type generally considered unprocessable:

37.

[C1 The mouse_a
[C2 the cat_b
[C3 the dog worried _b]
killed _a]
ate the malt.]

³ Note that the tensed version of (36) also includes the relative pronoun “who” in C3, whereas the untensed variation without “who were” has a zero subject. This pronoun would not be expected to increase processing difficulty for reasons discussed in the preceding section on referential specificity: because it is co-indexed with the head noun “teachers,” “who” is not introducing a new referent.

Just as each definite NP requires accessing a new referent, each verb in a sentence of this type requires (in addition to the integration process described by Gibson (2000)) accessing a time when the action took place. The three past tense verbs may, therefore, require successive jumps back in time when interpreted – first the time at which the dog worried the cat, then the time when the cat killed the mouse, and then the (necessarily earlier) time when the mouse ate the malt. Referring back to past times increases the processing difficulty of an already complex structure, since the times themselves constitute added referential elements alongside the referents introduced by the subjects.

1.2.2.2.2. Semantics of embedded clause verbs: Lexical aspect

Unlike NP/DP semantics (as discussed in the section 1.2.2.1), verb semantics has not been researched in detail as a source of difficulty in center-embedding. However, there are reasons to suppose that Aktionsart/lexical aspect may be relevant, based on semantic complexity and observations of acceptable center-embeddings. I will return to this matter in Chapter 2, Section 3, in relation to naturally occurring center-embeddings.

1.2.2.2.2.1. Categorizing lexical aspect

Verbs may be categorized semantically by what is termed *lexical aspect* or *Aktionsart*. This property was first described by Vendler (1967) and developed further by Dowty (1979: 51ff), and is therefore often called the Dowty-Vendler classification. Vendler's schema divided verbs into four classes: statives, activities, achievements, and accomplishments. Statives, such as *know* and *be*, are temporally unbounded (atelic) static situations. Activities, such as *run* or *dance*, are temporally unbounded dynamic situations. Finally, achievements and accomplishments both express changes of state. Achievements are punctual (occurring at one moment), such as *break the window* or *bite the cat*, whereas accomplishments are durative (requiring time to completion), such as *melted the ice* or *ate the mouse*. Activity verbs can also

be used telically, to create what is known as an active accomplishment, as in *we ran to the park* (as opposed to *we ran for ten minutes*, which is an activity).

Van Valin (2006) presents the following feature typology for Aktionsart, reproduced here as Table 1.2.

Table 1.2.: Van Valin's feature typology

State	+ static	- dynamic	- telic	- punctual
Activity	- static	+ dynamic	- telic	- punctual
Achievement	- static	- dynamic	+ telic	+ punctual
Semelfactive	- static	± dynamic	- telic	+ punctual
Accomplishment	- static	- dynamic	+ telic	- punctual
Active accomplishment	- static	+ dynamic	+ telic	- punctual

Verbs which are [-static] (all but statives) can be described as “something happening.” Verbs with [+dynamic] are those which involve action (i.e. can be characterized as “X did something”); [+telic] refers to the property of having an endpoint; and [+punctual] means that the event is not extended in time.

This way of categorizing verbs raises a question relevant to issues of processing in structures like center-embedding: which verb types are more semantically complex? Van Valin (2006: 164), following Dowty (1979), analyzes statives as bare predicates and activities as having a “do” component as formalized in (38-9):

38.

Stative: **dead'**(x) = x is dead

39.

Activity: **do'**(x, [cry'(x)]) = x cries

These are the simplest forms of lexical aspect; all others can be analyzed as having additional semantic components. Dowty (1979) offers a finer semantic analysis of the achievement and accomplishment categories. Achievement verbs can be considered to combine a stative plus an ingressive element, signifying the onset of a state (40).

40. INGR **shattered**'(x) "shatter [INTR]."

Another less common category is the semelfactive (Smith 2013: 56, Comrie 1976: 42): activity verbs with an added "once" modifier, meaning that the action occurred just once (41_:

41. SEML **do**'(x, [**sneeze**'(x)]) "sneeze"

Accomplishments (42), which involve a change of state occurring over time, consist of statives or activities (in the case of "active" accomplishments) combined with a "become" operator (Dowty 1979).

42. BECOME **frozen**'(x) "freeze [INTR]"

Accomplishments are therefore more complex than statives or activities.

1.2.2.2.2. Semantic complexity and its effect on center-embedding

Under the above analysis, accomplishments would be the most semantically complex type of verbs, statives and activities simplest. We have seen (in section 1.2.2.1.2.) that nouns which are semantically vague and lacking specificity of sense (e.g. *stuff*, *people*) may facilitate center-embedding when occurring as subjects of embedded clauses. With this in mind, we have a possible, hitherto unexplored, avenue of research for processing difficulty in center-embedding: does the lexical aspect of the verbs alter the acceptability and/or processability of the sentence? Much as a tense marker in a finite verb adds semantic information, the "become" operator of an accomplishment verb or the ingressive operator of an achievement constitute additional information. According to Gibson's (2000) processing theory, the verbs in C2 and the main clause present the highest integration costs, so manipulating these verbs (as well as that in C3) would be informative. We would expect to see that verbs

which are semantically simpler or less informative, i.e. statives and activities, would be prevalent at all three verb phrases.

1.2.2.2.3. Found examples

With regard to the possible role of lexical aspect, it is also worthwhile to look at some examples of center-embedded sentences that have been found “in the wild” or noted to be processable due to other observed facilitating factors. These (43-46) show a tendency toward simple lexical aspects, particularly the atelic stative and activity. Here I follow Dowty (1979: 66ff) on classifying verbs by aspect, and will discuss the lexical aspects of each in turn:

43.

[C1 The woman_a
[C2 someone_b
[C3 I knew __b]
brought __a]
left. (constructed example, Kluender 1998: 248)

In (43), the verb “to know” is a stative. As such, it may further contribute to the processability of the C3 clause, which is already facilitated by the indexical pronoun subject. The C2 and main clause verbs are achievements, which are more complex than statives but less so than accomplishments.

44.

[C1 The apples_a
[C2 that the girls_b
[C3 Bill watched __b]
collected __a]
were heaped up.
(constructed example, Hudson 1996)

The main clause of (44) is a stative predicate of location/position (Dowty 1979: 67), while C2’s “collected” could be considered an accomplishment verb and C3 an activity (since it is atelic).

45.

[C1 A lot of the housing_a
[C2 that the people_b
[C3 that __b worked in New Haven]
lived in __a]
was back that way] (Reich & Dell 1976)
(attested example, C3 activity, others stative)

In this attested example (45), “worked” in C3 is an activity verb (in context, the meaning is probably habitual; i.e. it refers to working on a repeated basis instead of one specific bout of work); the other two predicates are statives of location.

46.

[C1 The game_a
[C2 those boys_b
[C3 I met _b]
invented _a]
resembles chess.](Smith 1989: 56)
(attested example)

In (46), again the main clause verb “resemble” is a stative; C2 an accomplishment, and C3 an achievement.

Overall, these sentences show a predominance of statives (*live (in)*, *resemble*) and activity verbs (*work*, *watch*), the lexical aspects which appear semantically simplest in Van Valin’s (2006) analysis. At least one clause, in each sentence, has one of these simpler types of verbs. Whether these observations reflect the general frequencies of different verb lexical aspects or are particular to center-embedded sentences is not clear, but it is possible that an overall need to decrease memory/processing load may contribute to a prevalence of simpler aspects, more so in the embedded clauses.

These few examples, of course, are not sufficient to show a relationship between center-embedding processing and lexical aspect, but they are suggestive. Further research is needed to explore this connection in more detail, and further relevant data is offered in Chapter 2 with regard to naturalistic center-embedding results found through corpus search and everyday observation.

I now move onto more “global” factors that influence the processability of center-embedding: the prosody of the whole sentence (which is related to the relative lengths of clauses), and the possibility of similarity-based interference between components of each clause.

1.2.3. Prosody

So far, I have mainly focused on the effects of single words and inflectional markers, or the absence thereof, as factors affecting the processing difficulty or acceptability of multiple center-embeddings. This section concerns a more “global” factor – the prosody with which the whole sentence is, or can be, uttered; prosody in turn depends on the relative lengths of the main and embedded clauses, so it may have an effect in written as well as spoken sentences. Prosody has not received as much attention as some of the previously mentioned factors, such as noun phrase structure, and the existing research on English has focused on phrase length and pauses rather than other prosodic factors such as pitch contours (but see Féry & Schubö 2010 for relevant research in German and Hindi).

Some early research (Miller 1962, Fodor et al. 1967), discussed in subsection 1.2.3.1, suggested that complex center-embedded sentences are not conducive to naturalistic prosody, but that more expressive or natural (as opposed to monotonal or list-like) prosody could facilitate comprehension. More recent studies (Fodor et al. 2018, 2019), covered in section 1.2.3.2, have revisited the issue of prosody and shown that with the right prosodic contour – and clause lengths conducive to this prosody – even the types of double-object embeddings that are generally most difficult can become quite comprehensible. Finally, in section 1.2.3.3, I further explore the insights of these prosodic studies in relation to other facilitating factors.

1.2.3.1. Early research on prosody: production and comprehension

Psycholinguistic research of the 1960’s and 70’s revealed that center-embedded structures are unconducive to being read with normal sentence prosody, but also that hearing the sentences aloud with typical prosody (e.g. intonation indicating clausal breaks) might facilitate comprehension. Miller (1962: 755) found that center-embedded clauses were difficult to read aloud, and subjects would tend to read off such sentences like an unstructured random list of words (i.e. broken up into many short intonation phrases). However, he did not offer much

detail ("I will not summarize the quantitative results, but I think that some of the qualitative results are amusing.") (47) is one of Miller's stimulus sentences; as it has three levels of embedded object relative clauses and an excessively complex subject NP in the deepest clause (C4), it is quite unnatural and a serious processing challenge:

47.
 [C1 The race _a
 [C2 that the car _b
 [C3 that the people _c
 [C4 whom _c the obviously not very well dressed man called _c
 sold _b]
 won _a]
 was held last summer.]

Subjects did more closely approximate a normal intonation after rereading the sentence a few times, thus having what Miller (1962: 756) calls an "Aha!" experience when the sentence structure was finally comprehended.

J. A. Fodor et al. (1967) took a different approach to the question of center-embedding and prosody: rather than observing attempted sentence production, they used prosodic realization as an independent variable in one of several comprehension experiments. Subjects heard recordings of sentences read aloud either with a "neutral" or "expressive" prosody (these terms are not explained in detail, so the exact factors involved are not entirely clear). "Expressive" prosody was found to significantly facilitate response times and comprehension, which was measured by correct retrieval of subject-object relationships.

A somewhat more detailed approach to prosody was taken by Shaefer (1971). Shaefer's work focused primarily on the influence of context on comprehension of center-embedding, but also compared the effect of "natural and monotone intonation conditions." These conditions were defined as follows: "natural" sentences were spoken with emphasis on key nouns and verbs, pauses marking off the embedded clauses, appropriate emotional tones, and occasional filled pauses such as might occur in a normal conversation. In addition, clauses that were more

deeply embedded were spoken faster than outer clauses (Shaefer 1971: 52). In (48), a very complex sentence of depth 4, commas indicate pauses, and italics indicate emphasis:

48.

The number of *people*,
that that tiny *classroom*,
that the modern *lit* course,
that the *new assistant professor*
whom *all* the students *loved*
offered for the first time,
was *held* in,
jammed together,
just *amazed me*.

For “monotone” sentences, such stresses were avoided, but pauses were used at appropriate syntactic junctures; i.e. the sentences read in this manner were not completely “monotone” nor did they feature list intonation as in Miller’s results (Shaefer 1971: 53). Naturalistic as opposed to monotone prosody did facilitate comprehension, but only for sentences presented without context (Shaefer 1971: 74). Furthermore, Shaefer’s sentences were designed to be semantically plausible, with an obvious schema fitting nouns and verbs together, as can be seen in the above.

1.2.3. 2. More recent studies (JD Fodor et al.)

Following these earlier attempts, prosody was largely set aside as an object of psycholinguistic study for several decades due to technological issues, as noted by Fodor (2002ab). Based on the findings of Cuetos and Mitchell (1988) on cross-linguistic differences in ambiguity resolution, she suggests the “Implicit Prosody Hypothesis”: prosody always influences interpretations of sentences, even during silent reading. This idea has been experimentally confirmed (Gross et al. 2014). There is also evidence that implicit auditory representations of sentences in silent reading may facilitate deeper processing, improve comprehension, and

decrease errors (Zhou & Christianson 2016).⁴ Given that center-embedded sentences present processing challenges, it is likely that prosody is a factor in processing, regardless of whether a sentence is heard or read silently. In subsequent studies Fodor set out to bring this generally neglected factor to bear on center-embedding, and to explore how prosody and syntax clash in these sentences.

1.2.3.2.1. Prosodic realizations of center-embedding: Fodor & Nickels (2013)

Fodor and Nickels (2013) analyzed the different possible prosodic structures for a “minimal” doubly center-embedded sentence, one with three subject NPs and three predicates. A sentence like this is too long to be uttered as a single intonational phrase, and can be split into two prosodic units in different ways, as shown in (49), but most of them do not align with the syntax (in this and subsequent examples the double bar (||) indicates a major prosodic break):

49.

- a. The woman || the man the girl loved met died.
- b. The woman the man || the girl loved met died.
- c. The woman the man the girl || loved met died.
- d. The woman the man the girl loved || met died.
- e. The woman the man the girl loved met || died.

The underlined sequences in (a-d) fail to satisfy what Fodor & Nickels term the “syntactic coherence condition”: only elements which form a coherent syntactic unit should be grouped in an intonational unit. Another constraint, called Wrap, dictates that prosodic breaks should not fall within a constituent (Truckenbrodt 1999); prosodic breaks within the relative clause that modifies the subject NP would violate this constraint. Only (e) fulfills both the syntactic

⁴ Implicit prosody entails the existence of an inner monologue or “mental voice”. The nature and role of inner monologues in silent reading, and in cognition more generally, is not fully understood. J. D. Fodor (2002b: 115) notes that some people claim not to hear a “mental voice” when reading silently, but is skeptical of the accuracy of this introspective evidence. The analogous phenomena of aphantasia and hyperphantasia, which are variations in the existence and detail of mental imagery (Keogh & Pearson 2018, Zeman et al. 2020) suggest that some people may indeed lack inner monologues (see also Hinwar & Lambert 2021). In addition, anecdotal claims concerning lack of “mental voices” are abundant (e.g. Stewart 2020). If there exist genuine individual differences in the richness or existence of inner prosodic representation, that could account for some of the unexpected variation between subjects observed in later experiments, e.g. Fodor et al. (2019).

coherence condition and Wrap, by packaging the entire subject NP into one prosodic unit, but it suffers from another prosodic difficulty: the subject NP is much longer than the monosyllable one-word VP, creating a severe imbalance that makes the pattern unintuitive. It thus violates the prosodic constraint of uniformity (formulated by Ghini 1993:56), which requires that sentences should be parsed into equal-length prosodic units. Thus the syntax of center-embedded sentences is hard to reconcile with the requirements of prosody.

However, it is possible to create center-embedded sentences conducive to a more balanced prosody, by keeping the C2 and C3 short and lengthening the C1 verb phrase. A sentence like (50) fits into two prosodic phrases of about equal length:

50. The girl [_{C2} the man [_{C3} I love] met] || died of cholera in 1960.

This realization requires packaging two relative clauses into one prosodic phrase, which requires very short words and an unstressed pronoun in C3 (as previously noted, pronouns and especially indexical pronouns as C3 subjects appear to independently facilitate comprehension). Fodor et al. (2013, 2017) further note that longer center-embedded sentences can be divided into three prosodic phrases: the initial NP, the double relative clause modifying the NP (C2 and C3, in my notation), and the main clause VP (see also Fodor 2013). (51) illustrates this pattern:

51. NP1 || [_{C2} NP2 [_{C3} NP3 VP3] VP2] || VP1

This prosodic pattern, in turn, is easier to produce if C3 is relatively short and the main clause NP and VP longer, making the three prosodic phrases closer to equal in length as in (52):

52. The elegant woman || that the man I love met || moved to Barcelona.

On the other hand, if all constituents are lengthened, the sentence requires more than three prosodic phrases and will likely be produced with a list-like intonation (a process which may account for the reading attempts that Miller (1962) found so amusing). To demonstrate this

point, Fodor et al. (2013) note that a sentence like (53), with clause lengths conducive to splitting into four prosodic phrases, is hard to interpret syntactically:

53. [_{C1} The elderly Frenchwoman ||
 [_{C2} that the man
 [_{C3} the girl loved] ||
 met on a Mediterranean cruise] ||
 died last year in Maine.]

The syntactic difficulty comes from the prosodic break between the C3 and C2 verb phrases (“loved || met”) , which interrupts C2 after the closure of C3 (“the girl loved”), and thus makes it more difficult to reincorporate the “stranded” VP of C2 (“met on a Mediterranean cruise”) into the incomplete C2 of the previous prosodic phrase (“that the man”). This C2 VP (“met... cruise”) may be misassigned to the main clause, only to be replaced with the actual main clause verb (“died...”) when it occurs, and then simply forgotten by the parser (which Fodor et al. suggest as an explanation for the “missing VP” phenomenon, discussed in section 1.5).

1.2.3.2.2. Reading aloud center-embeddings: Fodor et al. (2017, 2019)

Fodor et al. (2017) confirmed the greater processability of the three-prosodic-phrase pattern through read-aloud experiments, where subjects were asked to rate sentences on perceived comprehensibility and acceptability. In these example stimuli, (54a) exemplifies what the authors call an “encouraging” combination of clausal lengths, whereas (54b) is “discouraging” – the short main-clause noun and verb (“the pipes... burst”) combined with the much longer embedded clauses (“that the unlicensed plumber... tried to repair”) are less conducive to a prosodic pattern that makes it comprehensible:

54.
 a. [C1 The rusty old ceiling pipes
 [C2 that the plumber
 [C3 my dad trained]
 fixed]
 continue to leak occasionally.]

- b.
[C1 The pipes
[C2 that the unlicensed plumber
[C3 the new janitor reluctantly assisted]
tried to repair]
burst.]

Miller's (1962) complex example repeated here as (47), in comparison, is incredibly discouraging. It is also interesting to note that longer NPs (e.g. "the rusty old ceiling pipes" as opposed to "the pipes") are more semantically specific, which would make them easier to retrieve at the relativized gap position, while also creating more difficulty when they occur between elements of a dependency (cf. Kluender 1992, Hofmeister 2011).⁵ Thus the facilitating effects of prosody go hand-in-hand with the effects of NP referentiality and specificity discussed earlier (section 1.2.2).

Continuing this line of research, Fodor et al. (2019) describe a follow-up experiment which added a "preview": all participants were asked to read a sentence aloud at first sight and then read it aloud again after reading it silently as many times as desired. The written stimuli offered no cues (e.g. internal punctuation or formatting) as to what prosody should be used in reading it aloud, in order to avoid biasing participants toward any particular reading. Participant recordings were assessed for conformity with the "optimal" pattern in (46), i.e. with the strongest prosodic breaks before and after C2, and weaker or no breaks within C2 or C3. Fodor et al. found that less-optimal prosodic patterns, indicating parsing difficulties, persisted in the second read-through, although prosodic phrasing was closer to the "optimal" pattern than in first readings, and all but one participant produced the optimal pattern more often after preview than in their first read. While preview generally improved performance, there was also significant variation between participants: some could produce the optimal prosodic pattern at first reading, without preview, whereas others could not produce it even after preview.

⁵ The three definite description subjects in (54b) may also contribute to processing difficulty, both because of their definiteness and because all three subjects are of the same referential form, producing similarity-based interference (see following section 1.2.4).

The authors therefore suggest that this difficulty of fitting doubly center-embedded clauses into a pronounceable prosodic pattern, one that takes into account the prosodic constraints mentioned above, may account (at least partially) for the rarity and difficulty of the construction. This optimal pattern requires C2 (the central sequence of two NPs and two VPs) to fit into one prosodic phrase that is ideally shorter (or at least not significantly longer) than either the main clause subject NP or the VP. Such sentences may be rejected as unacceptable by speakers not because of real syntactic constraints, but because of this syntax-prosody mismatch.

1.2.3.3. Prosody in relation to other facilitating factors

Fodor et al. (2019) also note that some doubly center-embedded sentences are fully processable, an observation consistent with the found examples I have presented in previous sections (e.g. 1.2.1.1.1). It is instructive to return to a few such easy examples in light of prosody; (55-57bc) are possible prosodic analyses of the (a) sentences, assuming that prosodic breaks align with the beginning and end of C2, as in Fodor et al's optimal pattern:

55.

- a. [C1 Books
 [C2 that people
 [C3 studying linguistics]
 buy]
 are expensive.] (Hudson 1996)
- b. Books || that people studying linguistics buy || are expensive

56.

- a. [C1 A book
 [C2 that some Italian
 [C3 I've never heard of]
 wrote]
 will be published soon by MIT press]
- b. ? A book || that some Italian I've never heard of wrote || will be published soon by the MIT press.
- c. ?? A book that some Italian I've never heard of wrote || will be published soon by the MIT press.

57.

- a. [C1 The woman
 [C2 someone
 [C3 I knew]
 brought]
left.]
- b. The woman || someone I knew brought || left

In (55), the subject (“books”) and the C1 VP (“are expensive”) are shorter together than the whole C2 (“that people studying linguistics buy”). Despite this prosodic mismatch, the sentence seems to be processable. This is probably facilitated by the nonfinite C3 verb (which allows the clause to be subjectless) and the fact that C3 is a subject relative clause. (56) likewise has a short main clause subject (“A book”) but a long main VP (“will be published soon”), while the entire C2 (“that some Italian [I’ve never heard of] wrote”) is about the same length as the VP, “will be published soon by the MIT press”. The sentence thus seems prosodically unbalanced if read as three phrases (56a), and slightly long for two phrases (56b). However, it seems easy to process because of the nonspecific subject of C2 (“some Italian”) and the C3 (“I’ve never heard of”), which simultaneously features an indexical pronoun subject, lacks a specific time reference due to being in present perfect tense, and has a stative verb (cf. Partee 1984, and see preceding section 1.2.2.2. on verb tense).

On the other hand, (57) may be too short for the three-phrase analysis, but it is nonetheless quite comprehensible. With a longer main clause predicate (58), it fits two prosodic phrases, one of Fodor’s alternate patterns that is difficult to achieve:

58. The woman someone I knew brought || left the academic conference abruptly

The simplicity of the pronoun subjects in C2 (indefinite *someone*) and C3 (indexical *I*) may obviate the need for prosodic amelioration by reducing the semantic content of the embedded clauses, and therefore easing processing.

Based on the above observations, “encouraging” prosody may not be a necessary condition for understanding easier center-embedded sentences, i.e. those with lexical and syntactic facilitating factors. Rather than being a decisive factor in itself, prosody is one factor among several. I now turn to a converse question: whether prosody can facilitate sentences that are otherwise pushing the limits of processability, despite other facilitating factors. Consider this marginal and very complex example (59), from Bever (1974), which has three center-embedded clauses but may still be processable:

59.

[C1 The pictures
 [C2 a reporter
 [C3 everyone
 [C4 I met]
 trusts]
 took]
 showed that arson caused the fire.] (Bever 1974)

The massive C2 in this sentence (“a reporter...took”) makes it difficult to fit into either the three-phrase or two-phrase pattern; a sentence this long, as Fodor et al. (2017) noted, risks being broken down into a list-like intonation of multiple prosodic phrases, and in addition a stress clash may occur between the four (stressed) verbs forming the string “met trusts took showed”. In addition, the short main clause subject (“the pictures”) would make a three-phrase reading like (60) feel unbalanced:

60. The pictures || a reporter everyone I met trusts took || showed that arson caused the fire.

Lengthening this the C1 subject with modifiers may help, but the length of the sentence still makes a prosodically acceptable reading difficult due to how many words must be packaged in one phrase:

61. The collection of high-resolution pictures || a reporter everyone I met trusts took ||
 showed that arson caused the fire.

These examples (55-7 and 59-60) do not appear to easily fit with Fodor et al.'s "good" prosody patterns (with regard to lengths, pauses, and breaks in intonation), so while conformity to the "good" prosodic pattern is clearly important, it may not be strictly necessary for comprehensibility if the sentence already has enough facilitating factors in its favor. Fodor et al.'s "encouraging" examples, though their C2s and C3s are shorter than those in examples like (56), still feature referential subjects and tensed verbs; therefore they would be fairly difficult were it not for the helpful prosody. All these results make clear that the difficulty of center-embedding is affected by a variety of linguistic factors, and as Fodor et al. (2019) describe, individual differences in implicit prosody may play a role as well.

In addition, other aspects of prosody besides pauses and intonation breaks are likely relevant to center-embedding, but this issue is largely unexplored for English. For instance, it is not clear whether the F0 range in a clause with a center-embedding differs from that of a clause without one, as is the case in German (Fery & Schubo 2010) and how pitch variation may facilitate comprehension of center-embedding. The interface between prosody and syntax as it relates to center-embedding remains to be fully understood.

1.2.4. Similarity-based interference

Another "global" factor that influences the processability of center-embedded sentences, and sentences more generally, is interference between elements of the clause (particularly noun phrases) that are similar along some parameter. Semantic and/or morphological similarity between components of a center-embedded sentence – particularly the three consecutive noun phrases that occur in a series of two center-embedded object relative clauses – contributes to the difficulty of retrieving filler nouns at their corresponding gaps. In the case of a sentence with multiple similar noun phrases, retrieval cues – such as a verb requiring an animate subject – may apply to more than one noun, making the cue less useful. The interference phenomenon demonstrates how the difficulty of center-embedding stems from general working memory

limitations, which are particularly pressing in real-time language use, and therefore provides further evidence that the difficulty of center-embedding is a processing issue rather than a syntactic constraint.

1.2.4.1. General overview

Interference between similar items is a generally attested memory phenomenon (see Lewis 1996a for a brief overview). In short-term memory, distractor items that are similar in some way to the item to be remembered impede memory of that item more than do dissimilar items (see for example Logie et al. 1990 on visual stimuli).

Effects of this type occur in processing long-distance syntactic dependencies, which require a word to be retrieved at a later point in the sentence (Lewis et al. 2006). For example, in (62), the verb “ran” requires an animate subject; since the word “cat” in the relative clause modifying the subject intervenes and fulfills that condition, it may interfere with the retrieval of “mouse” at the required position, impeding overall comprehension.

62. The mouse [the cat chased] ran away fast.

As will be explored in the rest of this section, similarity-based interference can contribute to the difficulty of center-embedded sentences in which the subject is modified by a relative clause containing another embedded clause.

1.2.4.2. Interference and center-embedding: Experiments and observed examples

Like many important phenomena relating to center-embedding, similarity-based interference was observed by Bever (1970: 338). He noted that “superficial similarity” between noun phrases and verb phrases makes center-embedded sentences harder to comprehend. Thus (63a) is harder to comprehend than (63b), according to Bever’s intuition. Of course, both of these examples are nonetheless very difficult due to previously discussed features: double object relative clauses with definite subjects and finite verbs.

- 63.
- a. The dog
 the cat
 the fox was chasing
 was scratching
 was yelping.
 - b. The dog
 the destruction
 the wild fox produced
 was scaring
 will run away fast.

The similarities which lend to the difficulty of (63a) take multiple forms – all three clauses have definite subjects referring to mammals and past progressive VPs. On the other hand, (63b) features semantically different noun phrases – the abstract “destruction” and the adjective “wild” modifying “fox,” while the verb phrases each feature a different tense/aspect marking.

Most subsequent experimental work concerning similarity-based interference has focused primarily on subject noun phrases. As previously discussed (section 1.2.2.1), the presence of the multiple consecutive subject NPs/DPs in a center-embedded sentence is a considerable cause of processing difficulty, especially if all of them introduce new referents. We now consider how similarities between these subject NPs/DPs can further add to or mitigate difficulty. First I will present a chronological overview of relevant experimental results and hypothesized models of the memory process involved (4.2.1), followed by a look at some found examples (4.2.2.) to assess how similarity between subjects, which may be hard to process, is avoided in practice.

1.2.4.2.1. Experimental results and models

1.2.4.2.1.1 Stolz (1967): Early experiments

Stolz (1967) was the first to experimentally confirm that center-embedded sentences with (semantically) similar subject NPs are harder to paraphrase or remember correctly. The examples in (64) are from Stolz (1967), where the sentence with NPs conducive to interference is marked “semantically neutral” and the one with different NPs “semantically supported”:

64.

- a. The children
 that the boy
 that the policeman saw
 discovered
noticed something. (“semantically neutral”)
- b. The vase
 that the maid
 that the agency hired
 dropped
broke on the floor. (“semantically supported”)

The semantically supported sentence (58b) also offers a clear schema linking nouns and verbs; i.e. it is obvious which noun is the subject or object of which verb from the lexical semantics.

1.2.4.2.1.2. Lewis 1996: Interference between partial constituents

Lewis (1996a) formalized these observations, and combined insights from syntactic processing and memory research to create a general model of interference in short-term memory and its impacts on sentence processing. In this model, syntactic constituents are tagged in working memory as phrasal heads and/or dependents. In a sentence with an object relative clause modifying its subject like (65), two phrases (“the cat” and “the bird”) are both tagged in working memory as clausal subjects, producing a potential for interference.

65. The cat [that the bird found] jumped

If there is another embedded clause with an overt subject, as in the classic difficult examples of doubly embedded relative clauses, then there are three determiner phrases tagged as subjects, as seen in (66):

66. The cat [that the bird [that the dog chased] found] jumped

Double embedding therefore places even more of a strain on working memory because there are three, rather than two, constituents indexed as subjects. Lewis (1996) postulates that if three or more subjects must be held in working memory under the same syntactic role, one may be dropped, or interference may occur (causing difficulty attributing each noun to its correct slot). Because of this, a sentence like (66) would pose particular processing difficulties due to the confusability between “cat,” “bird,” and “dog,” three nouns all referring to animals; both the sheer number and the similarity between them contribute to the confusability issue. Center-embeddings would therefore be easier to process if (all else being equal) the three subjects were different from each other along some parameter, such as lexical semantics (e.g. if not all share a feature such as animate or human).

This “magical number” two or three appears in a variety of verbal working memory restrictions (McElree 2001, Lewis 1996: 109), as a restriction on how many similar, potentially confusable, elements can be kept in memory at the same time. Lewis’s predictions concerning memory limits and interference have been generally upheld by experimental findings, as explored in the subsequent section. Similarity between noun phrases can take several forms, including semantic similarity (e.g. nouns referring to humans) and semantic similarity (type of noun phrase, such as name or definite description); these parameters of similarity both appear to contribute to processing difficulty, as shown below.

1.2.4.2.1.3. Gordon et al. (2001): Interactions between similarity and other factors

Similarity between subjects appears to interact with other factors involved in center-embedding processing, adding to or mitigating difficulty. For example, Gordon et al. (2001) investigated similarity-based interference as it interacts with the differences in processability between subject and object relative clauses and with referential form of NPs – which, as previously discussed in Section 1.2.2.1, are relevant to the difficulty of center-embedding. They found that the discrepancy in reading time between subject (67b,d)

and object relative clauses (67a,c) was significantly greater when both the main and relative clause contained a definite NP (67a,b), compared to when the relative clause contained either an indexical pronoun or a proper name (67c,d).

67.

- a. Definite NPs, object RC:
The banker [that the barber praised] climbed the mountain
- b. Definite NPs, subject RC:
The banker [that praised the barber] climbed the mountain.
- c. NP and pronoun, object RC:
The banker [that you praised] climbed the mountain
- d. NP and pronoun, subject RC:
The banker [that praised you] climbed the mountain.

This result neatly demonstrates the way in which linguistic factors interact to create difficulty with even one-level center-embedding. A sentence like “The banker that the barber praised _ climbed the mountain” has several factors stacked against it: the definite subjects, tensed verbs, and an object relative clause. Changing the relative clause subject to either a pronoun (especially an indexical) or a proper name not only makes the clause easier, in itself, but avoids the retrieval-cue overlap that two definite subjects would create.

A follow-up experiment by Gordon et al. (2001) used cleft sentences involving either definite descriptions or names. The results clarified that names also create similarity-based interference in comprehension (i.e. a sentence with two proper names in subject position is more difficult than one with a name and a descriptive NP), so the difference cannot be attributed to the easier processing of some types of subjects alone. However, Gordon et al. (2001) did not use stimulus sentences with semantically different referential subjects (e.g. humans, animals, and inanimates), as did Stolz (1967), so it is not clear if the results of their first experiment stem from definiteness per se or from other parameters of semantic similarity (e.g. “the banker” and “the barber” both refer to humans, and are phonetically and morphologically similar as well).

Taken together, these experimental findings suggest that both morphosyntactic and semantic differences between the subjects of the clauses mitigate the difficulty of

center-embedding. Specifically, if the two consecutive subjects in a sentence with one embedded clause are both definite descriptions, then the sentence is harder to process than if one subject is a pronoun, and a comparable effect occurs with names. Furthermore, these results again confirm that there is a cumulative effect from the factors that create processing difficulty. For example, a center-embedded sentence with definite subjects all referring to humans is more difficult than one with definite subjects that differ in semantic features.

1.2.4.2.1.4. Lewis & Vasishth (2005): retrieval cue overlap

Additional experiments have confirmed that similarity-based interference seems to be worsened when more features are shared between confusable noun phrases. Lewis & Vasishth (2005: 380), in presenting a computational model (the ACT-R model) of sentence processing and memory, further analyzed similarity-based interference as a result of retrieval cue overlap. Overlap of retrieval cues means that the more items are associated with a particular semantic cue (e.g. human or animate), the less effective this cue is for retrieval of any one item. It follows from this notion that a sentence with multiple semantically similar noun phrases, such as classic multiple object relative clause center-embedding, will be hard to process. Both the sheer number of noun phrases and the presence of cue overlap between them contributes to difficulty. A cue for one noun (e.g. a gap or a verb) may lead to the retrieval of another, unintended referent. Since a sentence with two center-embedded object relative clauses constitutes a string of three noun phrases with three corresponding verb phrases, the possibility of interference is substantial, as the nouns may share semantic features. Under the ACT-R model, syntactic elements are not represented in serial order during parsing, but are accessed by retrieval cues (such as a verb that requires a subject noun, or features like animacy), with the most recent element being most easily activated (Lewis & Vashisth 2005: 404). Therefore center-embedded object relative clauses present a particular difficulty because they require nouns to be matched to verbs in a specific serial order (last-in-first-out). The more semantically similar the nouns, the

more likely interference may occur, resulting in processing slowdown or error. The predictions of this computational model match reading time differences between subject and object relative clauses (Lewis & Vasishth 2005: 394) and have been further confirmed experimentally, as demonstrated in the following section.

1.2.4.2.1.5. Van Dyke (2007): confirming the effects of semantic similarity

Reading time measures (Van Dyke 2007) also provide evidence that similarity-based interference impedes comprehension at the point in a sentence where a noun must be retrieved. When a sentence with an embedded clause modifying the subject NP is processed, this NP must be retrieved after the intervening clause, at the point where its corresponding verb appears. Similarity between noun phrases, under these circumstances, creates difficulty in the retrieval of the correct subject. Specifically, retrieval of the correct noun phrase is more difficult if there is another “eligible” noun phrase in addition to the actual filler, i.e. one that can plausibly fit the context due to its semantics (Van Dyke 2007). Thus, a slowdown in reading time at the main verb phrase occurs in “high interference” sentences like (68b) but not in “low interference” sentences like (68a).

68.

- a. The worker was surprised that the resident who was living near the dangerous warehouse *was complaining* about the investigation. (low interference)
- b. The worker was surprised that the resident who said that the neighbor was dangerous *was complaining* about the investigation. (high interference)

In the “high interference” case, “the neighbor” interferes with the retrieval of the DP “the resident,” since it denotes a human and also occupies a subject slot in its own clause. It is therefore tagged as a potential subject for the VP “was complaining”. By contrast, in the “low interference” sentence, no eligible subject for “was complaining” occurs between the subject and its verb, so there is no slowdown.

1.2.4.2.2. Attested examples: avoiding similarity

As with the factors discussed previously, we would predict that naturally observed and attested processable examples of double center-embedding would avoid similarity-based interference through their particular choice of noun phrases. That is exactly the case – such sentences have nouns and verbs that are varied in structure and/or semantics. For example, in addition to having an indexical pronoun in C3 (a facilitating factor discussed earlier), (69) has semantically quite different noun phrases in C1 and C2, and the verb phrases differ in tense and lexical aspect too – i.e. the C1 verb is present tense and stative, whereas the C2 and C3 verbs are past-tense achievements.

69.

[C1 The game_a
 [C2 those boys_b
 [C3 I met __b]
 invented __a]
resembles chess.] (Smith 1989: 56)

By contrast, this experimental example (70) constructed by Hudson (1996) is noted as very difficult; not only do the embedded clauses feature bare plural subjects, all NPs are bare plurals referring to humans, and the two in C2 and C3 are terms for professions:

70.

[C1 People_a
 [C2 that politicians_b
 [C3 who journalists interview __b]
 criticise __a]
can't defend themselves well.

Subject relative clauses in C3, in addition to their general processability advantage, also avoid a potential source of interference by not introducing a new subject that could potentially interfere with that of the other clauses, as they have only a WH pronoun coindexed with the C2 subject. This is evident, along with a facilitating (semantic) difference between C1 and C2 clause subjects, in this example (71) of my own observation:

71.

I regularly talk about how much I dislike kids, but
[C1 the things_a
 [C2 people_b
 [C3 who_b profess utter devotion to their welfare]
 do __a to them]
appall me.] (from <https://imgur.com/gallery/OmXRxNy>)

Since the C3 subject relative clause does not introduce a new subject noun phrase, there are only two potentially confusable noun phrases (*things* and *people*), and they differ along semantic parameters, although they are both bare plurals.

Another example of my own observation, (72) may illustrate how similarity-based interference can interfere with production as well as comprehension:

72.

[C1 The idea that
 [C2 [_]
 [C3 state formation is not a violent process
 (a fairly well established thing in the literature)]
 is somehow pro-genocide]
is, I don't know, silly? Laughable? Facile?]
<https://www.metafilter.com/195994/The-brakes-are-wearing-thin#8273742>

The context for this sentence was a discussion of the argument, expressed in C2, that the foundation of new countries does not necessarily involve violence, and the counterclaim that this idea constitutes genocide apologism. A fully correct version of the sentence would begin with two instances of “the idea that” or a synonymous phrase. The similarity between these two DPs heading complement clauses, along with the nature of the three clauses themselves (all have the verb “is”), may have caused this error where either the C1 or C2 subject was dropped. A related phenomenon concerning omitted verb phrases is discussed in Section 5.

I have previously discussed how variation in the referential form of noun phrases – replacing nouns with pronouns or quantifiers – can facilitate processing by avoiding the introduction of new discourse referents. The difference in structure between these varied noun

phrases, in itself, may also make the sentence more processable, as evident in these examples (repeated here as 73) discussed in Section 1.2.2.1.1:

73.

- a. [C1 The woman
 [C2 the man
 [C3 the host knew]
 brought]
left.]
- b. [C1 The woman
 [C2 someone
 [C3 I knew]
 brought]
left.]

In (73a), there are three consecutive definite subjects all referring to people, but in (73b), there is only one such subject, in C1, and the other two subjects are a quantifier (someone) and an indexical pronoun, so there is less room for confusion. The dimensions of NP similarity involved in similarity-based interference vary across languages depending on the presence or absence of e.g. case marking, as will be shown in relation to Japanese and Korean in section 1.4 below, but similar memory principles apply in all cases.

1.2.5. Concluding thoughts: Facilitating factors in English

In this section I have discussed the factors that facilitate processing of multiple clausal center-embedding in English. The main factors that have received attention in experimental research are clause type (complement vs. relative clause, subject vs. object relative clauses) and combinations thereof, clausal subjects (particularly with regard to specificity of reference and sense), verb inflection and lexical aspects, clause length and prosody, and similarity-based interference (particularly between subjects). Across all of these results, a common thread can be traced: center-embedded sentences are more acceptable when the embedded clause is simpler in semantics and introduces fewer new referents. This can manifest in different ways: a subject such as a pronoun that does not introduce a new referent, possibly a verb form without

tense inflection or telicity (i.e. a stative or activity verb), or a subject relative clause. Interference between components such as the subjects of the clauses also makes processing more difficult, so center-embedded sentences are more processable when the subjects are not similar in morphology or semantics. Real-life observed examples of center-embedding tend to strongly exemplify one or more of these factors, in striking contrast to the “classic” examples that are very difficult and often held up as evidence for the unacceptability of center-embedding in general.

1.3. Facilitating factors: Other SVO languages and the possible role of morphology

Work on center-embedding in SVO European languages besides English is limited, but the studies that have been carried out suggest that center-embedding is generally difficult and disfavored in the three Romance languages that have been studied in this respect: French (Section 1.3.1.), Spanish (1.3.2), and Italian (1.3.3). The question of whether the same factors that facilitate center-embedding in English also apply to these languages is not well-explored. However, factors that are not available in English, e.g. verb person and number agreement marking, may affect processing, though evidence regarding these effects is limited. In the case of the Romance languages under discussion, the presence of agreement marking may make center-embedding more acceptable than in English because it provides clear cues as to which subject matches which verb, and/or facilitates differentiation between nouns and verbs (see Section 1.3.1 and 1.3.2). Even when these factors are not present in a given sentence, language-specific differences in processing strategies may make speakers more adept at understanding complex embeddings, as postulated in the cue validity account of Bates & MacWhinney (1989); this effect in Italian is discussed in Section 1.3.3. However, the data is limited and the cue validity account may not provide a strong explanation for the results.

1.3.1. French

Multiple center-embedding of object relative clauses seems to present difficulties in French, as in English. French, like English, has SVO default order, which means that clauses modifying subjects are center-embedded. I summarize two relevant studies in this section.

1.3.1.1. Peterfalvi & Locatelli (1971)

In French, as in English, multiple center-embedding of clauses is confirmed to produce difficulty, although the difficulty may be mitigated by inflectional morphology factors that are not present in English. Peterfalvi & Locatelli (1971) tested speakers of French on center-embedded sentences such as (74) using comprehension questions. They found that comprehension clearly declined with depth of embedding – i.e. sentences with two center-embedded clauses were more difficult than those with just one. This added difficulty occurred whether the sentences were presented in speech or writing. However, comprehension improved if the nouns in the sentence fit into a semantic schema, e.g. “student,” “teacher,” “inkwell,” and “notebook” in (74) (an example of a sentence with a less-clear schema is not provided):

74.

```
[C1 L'encrier
      [C2 que l'élève
            [C3 que le maître punit, ]
            renverse, ]
tache le cahier. ]

[C1 The inkwell
      [C2 that the student
            [C3 the teacher punished ]
            overturned ]
stained the notebook. ]
```

The stimuli used in this task consisted of “classic” difficult center-embeddings – i.e. doubly embedded object relative clauses with definite DP subjects and tensed verbs, such as the above example. The authors did not test the sorts of lexical facilitating factors that have since been explored in English: e.g. using indexical or other pronouns as subjects (Section

1.2.2.1), or verbs without tense marking (Section 1.2.2.2). However, they explored the effect of tense by varying the tense of all the verbs in the sentence: present, past (*passé composé*), or imperfect (examples of these conditions are not given). Sentences with two levels of center-embedding and all three verbs in the imperfect tense were slightly better comprehended than sentences of the same complexity in other tenses. The authors attribute this result to the presence of a consistent suffix (*-ait*) in 3rd person singular which makes verbs easier to distinguish from nouns.

Aside from the effect of verb morphology, these results seem broadly similar to what has long been observed in English: doubly center-embedded object relative clauses with descriptive DP subjects are hard to comprehend. However, it must be said that comparisons to “easier” forms of center-embedding have not been carried out in French. In addition, French has a much richer verb inflectional system than English (although in many cases the inflections are pronounced identically and only distinguished in spelling). This may contribute to the comprehensibility of difficult sentences, although it is hard to draw definite conclusions from the limited experimental evidence.

1.3.1.2. Amy & Noizet (1978)

Further experimental evidence suggests that center-embedding is more difficult than right-branching in French. Amy & Noizet (1978) performed another comprehension experiment which only used “reversible” sentences, i.e. those where the DPs were all semantically similar and could plausibly be either subject or object of the verb, to address syntactic comprehension strategies alone. The authors provide (75), which contains a single center-embedding within a right-branching clause, as an example of “reversibility,” i.e. the subjects and objects can be interchanged to produce a sentence that still makes sense and is plausible:

75.

Le taxi double la moto
DEF taxi overtake DEF motorcycle
 que la voiture
 REL DEF car
 qui suit le camion
 REL follows DEF truck
 klaxonne
 honks

“The taxi overtakes the motorcycle that the car which follows the truck honks at.”

Note that, since all the DPs refer to vehicles, a sentence with this sort of “reversibility” also presents major similarity-based interference, a factor that would add particular difficulty if the structure was center-embedded.

The authors contrasted performance on doubly center-embedded sentences, sentences with one center-embedded and one right-branching clause (such as (75) above), and those with two right-branching clauses (examples of full sentences are not given for all structures), and confirmed that double-center-embedding was the hardest to comprehend. Again, these results are broadly similar to those for English, i.e. double center-embeddings were the most difficult and sentences with only right-branching the easiest to comprehend, and the sentences used are highly challenging for processing in other ways.

Since these two studies were published decades ago, no further research has specifically addressed the processability of center-embedding in French, or presented a detailed exploration of the facilitating factors (e.g. referential form) observed in English (see section 1.2). However, some studies have explored the processability of center-embedding in other Romance languages compared to equivalent sentences in English, and I will now discuss their findings and possible explanations for the results.

1.3.2. Spanish vs. English

There is experimental evidence that center-embedding may be more processable in Spanish than in English, due to word order and inflectional factors. Spanish has more flexible

word order than English (though the default order is SVO) and a complex verb inflectional system in which the distinctions are phonologically preserved, unlike in spoken French.

Based on these properties, Hoover (1992) argued that Spanish speakers rely more on the inflection of verbs (e.g. number and person agreement) and less on the whole clause to comprehend sentences, compared to English speakers (Hoover 1992: 280). Spanish and English therefore differ with regard to *cue validity* (MacWhinney & Bates 1989), i.e., how informative a feature is regarding the meaning of a sentence; in English, word order is a more valid cue, but in Spanish, it is less valid and inflection is more valid. On the basis of this assumed difference in processing strategies, Hoover (1992) hypothesized that Spanish speakers would perform better than English speakers at comprehending center-embedded sentences, in which clauses are interrupted but verb inflection is not affected.

This hypothesis was tested with two parallel experiments, in which English and Spanish speakers read sentences in their native languages with up to three center-embedded (object relative) clauses and third person singular definite human subjects, and were then tested with comprehension questions. Spanish speakers performed better than English speakers with doubly center-embedded sentences like (76). Specifically, while English speakers showed a decline in comprehension between one and two levels of center-embedding, Spanish speakers' performance did not decline.

76.

[C1 El carnicero
[C2 que el camarero
[C3 que el boxeador ayudó]
mató]
avisó al gitano.]

[C1 The butcher
[C2 that the waiter
[C3 that the boxer helped]
killed]
warned the Gypsy.]

To test the specific role of inflectional differences, Hoover (1992) also used center-embedded sentences where one of the (third person) subjects was pluralized, with appropriate verb agreement in Spanish. In English, the inflection of past tense verbs is the same for singular and plural subjects, whereas Spanish marks plural agreement in past tense for third-person subjects. If Spanish speakers were relying on morphological cues for processing (i.e. to determine which subject went with which verb), they would be expected to perform better on sentences with a combination of singular and plural subjects, where another cue is present, and have a greater advantage over English speakers. There was no such effect of pluralization (Hoover 1992: 292), suggesting that Spanish speakers were employing a different parsing strategy than English speakers across all sentences and not simply using inflection cues when available.

However, neither Spanish nor English speakers could easily comprehend sentences with three levels of center-embedding (77):

77.

```
[C1 The editor
    [C2 the waiters
        [C3 the athlete
            [C4 the plumber mistrusted]
                grabbed]
                    accompanied]
                        bothered the biologist.]
```

These sentences are, again, the typical sort of highly difficult center-embedded stimuli which early psycholinguistic work (in English and elsewhere) focused on. The difficulty-increasing factors discussed in Section 1.2 are on display here: the subject DPs are definite and introduce new referents, the verbs are tensed, and furthermore the subjects all refer to humans (generally by profession), which introduces similarity-based interference. In addition, there were no clear semantic cues to match up subjects to predicates, and in Spanish stimuli like (76), all the

subjects were third person singular, so verb agreement could not be used as a cue to which subject went with which predicate.

However, as mentioned above, Hoover (1992) found that the presence of differential verb agreement did not seem to influence comprehension in Spanish: when one of the subjects was plural and the corresponding verb had appropriate agreement, comprehension was not significantly different from the all-singular versions (Hoover 1992: 292). This result suggests that Spanish speakers are using a different processing strategy than English speakers, one less reliant on word order to discern the roles of the DPs, even in the absence of inflectional information that could aid in parsing: i.e., when all the DPs in a Spanish sentence are third person singular, verb inflection cannot be used as a cue to determine which verb matches which subject. Therefore, it appears that Spanish speakers, due to language-specific use of cues, perform better than English speakers on equivalents center-embedding even in the absence of facilitating morphology not available in English. Hoover proposes (1992: 292-3) that Spanish speakers rely less on word order cues than English speakers, since the subject-verb-object word order of Spanish is more flexible than in English, making word order less useful as a cue to meaning. The lack of difference in performance between all-singular and singular/plural sentences is also unexpected on similarity-based interference grounds – three DPs or verbs all bearing singular inflection would be expected to create interference. Therefore these results imply that Spanish is overall more “tolerant” of center-embedding than English, though for reasons that are not entirely clear. Since Spanish speakers evidently comprehend multiple center-embedding better than English speakers even without facilitating morphological cues, morphological differences alone cannot provide a full explanation.

It would be informative to see whether the same difference occurs when sentences featuring more facilitating factors – e.g. indexical pronoun subjects in embedded clauses – are used in each language. In the case of these easier sentences, any difference in language-specific parsing strategies may become less relevant, but the data here are lacking.

1.3.3. Italian vs. English

Another SVO language where center-embedding presents processing difficulties broadly similar to English is Italian, although as with the previously discussed languages, some specific morphological factors and the resultant use of different cues by speakers may mitigate the difficulties presented (Bates et al. 1999). Italian has SVO order by default, but allows word order variation for pragmatic reasons, and features subject-verb agreement for person and number, whereas English word order is more rigid and agreement more limited. These features of Italian seem to facilitate processing of sentences with one center-embedded relative clause – even in sentences where agreement would not disambiguate between possible noun-verb assignments, because of the way speakers use different cues. Specifically, Italian speakers (like Spanish speakers as discussed above) pay more attention to agreement and less to word order than do English speakers. Being less reliant on word order cues, Italian speakers are thus better at processing center-embeddings, according to Bates et al. (1999). However, whether the cue validity account truly explains these results is not clear.

Bates et al. (1999) performed a series of experiments measuring comprehension accuracy and reaction time to compare sentence processing between English and Italian, with attention to word order variations and the positioning of relative clauses. Some of these experiments addressed the way that speakers of each language deal with center-embedding (of a single clause), and how it is affected by different cues including word order and subject-verb agreement. English, as previously discussed, relies heavily on word order to convey the role of a verb's arguments, but Italian has richer subject-verb agreement and more flexible word order (meaning that word order has lower cue validity than in English).

The prediction that center-embedding is easier to process in Italian was borne out. In a reaction-time experiment on sentences with one center-embedded relative clause modifying the subject, Italian speakers showed less of a slowdown than did English speakers on equivalent

sentences such as (78) (for which the authors give only the English translations); the effect held for both subject and object relative clauses:

78.

- a. The secretary [that the doctor sees] shoots the cook (object RC)
- b. The secretary [that sees the doctor] shoots the cook (subject RC)

The authors suggest, on this basis, that center-embedding presents greater processing costs in languages that strongly rely on word order (such as English), as opposed to languages which rely more on morphology and other cues besides word order (Bates et al. 1999: 110). This result is consistent with the observations of Hoover (1992) in Spanish: in SVO languages with richer inflection and more flexible word order, speakers are less reliant on word order as a cue, and hence can handle center-embedding better than English speakers.

However, the reason that speakers of Romance languages perform better on sentences in which agreement does not offer any extra information matching subjects to verbs is not entirely clear. Hoover (1992) and Bates et al. (1999) assume that the greater comprehensibility of center-embedding in Spanish and Italian, compared to English, rest on the former languages' use of morphology as a cue. This cue validity account, however, does not provide a clear explanation for why performance is still better on sentences with no facilitating morphological cues, e.g. if all the DPs are third-person singular, and the sentence offers no obvious semantic/pragmatic cues as to which are the subjects of which verbs. Therefore, factors besides morphology must be at work.

One possible explanation would involve language statistics: if morphological factors in languages like Italian make center-embedding more processable than in less inflected languages like English, then center-embedding may occur more frequently. This would in turn make speakers more adept at processing center-embedded sentences that would otherwise be problematic due to a lack of overt morphological or semantic cues to comprehension. I will discuss related hypotheses concerning the missing VP illusion – in which ungrammatical center-embedded sentences are perceived as grammatical – below (Section 1.5.1.3), and

present evidence from corpus studies concerning differences in the prevalence of center-embedding across languages in Chapter 2.

1.3.4. Conclusion on SVO languages

These limited findings all suggest that even within typologically similar languages, the acceptability and processability of center-embedding may be contingent on language-specific factors such as morphology and word order flexibility. Even so, sentences with two center-embedded relative clauses or complement clauses may present difficulties if other factors, such as animacy and similarity between subjects, are not conducive to comprehension. Whether all of the same factors that facilitate center-embedding in English apply to other languages with similar syntax is not well-understood, as the studies at hand have not addressed many of these factors in detail. In particular, the possible role of reference form for clausal subjects has not been explored. However, corpus studies, discussed in Chapter 2, reveal that SVO languages, including English, French, Italian, and Spanish, all have a similar and very low rate of center-embedding in naturalistic discourse.

I will now turn to languages with a different default word order, namely the SOV languages Japanese and Korean. In these head-final languages, center-embedding of complement clauses is forced by the default word order, and relative clauses may be center-embedded as well. The processability and comprehensibility of multiple center-embedding is affected by broadly similar factors as in SVO languages.

1.4. Center-embedding in SOV languages

1.4.1. General overview

As discussed in Section 1.1., the prevalence of center-embedding in languages may vary with syntactic typology, specifically the placement of the verb relative to the object or complement. Some features of verb-final languages are more conducive to center-embedding than verb-medial languages, and in this respect Japanese and Korean are particularly well-studied. Most notably, complement clauses (of bridge verbs such as *to think, believe, know*) in verb-final languages will be center-embedded if default word order is maintained, as demonstrated in these abstract examples (79):

79. Center-embedded complement clauses

- a. [Subj1 [S] V1]
- b. [Subj1 [Subj2 [S] V2]] V1]

This pattern can be seen in the following Japanese (80) and Korean (81) examples:

80. *Japanese*

Haha-ga
Mother-Nom
titi-ga
father-Nom
hukigana akatyan-ga naita to
fussy baby-Nom cried that
itta to
said that
omotteiru
thinks

"My mother thinks that my father said that the fussy baby cried."

81. *Korean*

Sunhi-nun
S -Top
Chelswu-ka
C -Nom
Yenghi-ka uless-tako
Y -Nom cried-that
malhayss-tako
said -that
mitnunta
believes

"Sunhi believes that Chelswu said that Yenghi cried." (from Hagstrom & Rhee 1997)

SOV languages tend to have prenominal relative clauses, which mean that clauses modifying the main clause object are center-embedded, but those modifying the subject are not; i.e. they do not interrupt the main clause (as in 82ab). On the other hand, if an otherwise head-final SOV language has head-initial (instead of head-final) relative clauses, then clauses that modify both subjects and objects will end up center-embedded (Kuno 1974), as shown in (82cd). In the case of a clause modifying the object (82c), there is also a string of three consecutive NPs, which would be potentially able to create similarity-based interference:

82.

Prenominal RCs:

- a. Modifying object: [Subj [RC]-Obj V]: N [[N V] N] V
- b. Modifying subject: [[RC]-Subj Obj V]: [[N V] N] N V

Postnominal RCs:

- c. Modifying object: [Subj Obj-[RC] V]: N [N [N V]] V
- d. Modifying subject: [Subj-[RC] Obj V]: [N [N V]] N V

Kuno (1974) suggests that the word order combination of final verbs and postnominal relative clauses would be uncommon, to avoid center-embedding such as occurs in (82cd). In fact, contrary to this assumption, head-final languages with head-initial relative clauses are almost as common as those with consistently head-final relative clauses: 113 of the former and 132 of the latter are attested in the WALS database (Dryer 2013). Japanese and Korean, conversely, have prenominal relative clauses, as do some Turkic languages, such as Turkish (Johanson & Csato 2015: 220).

In the following section, I will discuss findings concerning Japanese and Korean, which have been the most extensively studied SOV languages with regard to center-embedding. In these languages, multiple center-embeddings may be permissible and processable when the equivalent would not be acceptable in an SVO language. These findings challenge any assumption that multiple center-embedding is categorically unacceptable or forbidden across languages.

Relatedly, the acceptability of double center-embedded complement clauses in Japanese and Korean contradicts assumptions like the “principle of two sentences” (Kimball 1973), which states that the parser cannot process constituents of more than two sentences simultaneously. From this principle follows the assumption that sentences with more than one level of center-embedding are not processable. Kimball’s principle was based on English, but it does not fully generalize cross-linguistically (Hagstrom & Rhee 1997), and as previously discussed, it is not a hard-and-fast rule for English (or other SVO languages) either, since center-embedding can be made acceptable by various facilitating factors.

SOV languages also present some particular conceptual difficulties for theories of sentence processing. As explored by Inoue & Fodor (1995), the syntactic properties of Japanese pose issues for parsing models which require that the verb be available for a clause to be comprehended; since Japanese is head-final and the verb thus normally follows all of its arguments, it would not be possible for a clause to be interpreted until the very end. These same properties mean that complement clauses in Japanese are center-embedded if the default word order is followed.

Japanese and Korean allow multiple center-embeddings in cases where comparable structures would be unacceptable in English or other SVO languages. The extent to which each language permits center-embedding, and the role of various facilitating factors in making sentences more processable and acceptable, is discussed below.

1.4.2. Japanese

1.4.2.1. Overview

In Japanese, relative clauses are prenominal and sentences normally verb-final; i.e. order is left-branching by default. Therefore, complement clauses are center-embedded by default, as described above. This word order also results in relative clauses that modify objects (but not subjects) being center-embedded with default word order, as shown in (82). It is generally known that center-embedding of relative clauses that modify objects in Japanese,

though forced by the default word order, is harder to process than the non-center-embedded structures which may be created by dislocation (e.g. Hakuta 1981, discussed in more detail in Section 1.4.2.2.1.). This has been confirmed by several experimental studies (Section 1.4.2.2.2.). In addition, other studies have explored the factors which make center-embedding more processable in Japanese: type of clause (Section 1.4.2.2.3.), including complement vs. relative clauses, and subject vs. object relative clauses; morphological and semantic similarity between the subject NPs (1.4.2.2.4.) including case marking (1.4.2.2.4.1.); and the transitivity of the deepest embedded clause C3 (1.4.2.2.5.). These factors broadly parallel those observed in English and other SVO languages, and in addition, the presence of case marking in Japanese may facilitate the acceptability of center-embedding, by decreasing one possible source of similarity-based interference between the subject noun phrases of clauses.

1.4.2.2. General processability of Japanese center-embedding

While center-embedding of complement clauses and relative clauses modifying objects is forced by word order in Japanese, it still appears to present processing difficulties broadly comparable to those in English and other SVO languages. Clauses that are left-branching or extraposed are more easily processable than center-embedded clauses, and center-embedded clauses may vary in processing difficulty depending on the location within the main clause (e.g. between subject and object, or between object and verb).

1.4.2.2.1. Hakuta (1981): Center-embedding vs. left branching

Japanese relative clauses that are left-branching or extraposed appear to be more easily processable than equivalent center-embeddings. Hakuta (1981) studied the acquisition of relative clause comprehension by Japanese-speaking children under age 6, and found that center-embedded (single) clauses were more difficult to comprehend than left-branching ones (Hakuta 1981: 214).

However, not all center-embedded clauses are equally hard to process. Hakuta also found that right dislocation can make center-embedded sentences more processible while retaining center-embedded structure (i.e. keeping the subordinate clause within the main clause, not at a periphery). Sentences with a center-embedded relative clause modifying the object (the default position of which is between subject and verb, N[NV]NV) can be modified through right dislocation of the noun phrase N3 bearing the clause, as Hakuta (1981: 221) illustrates with the abstract examples (83). Here *-ga* is the nominative case marker, *-o* is the accusative marker, and the underlined noun N3 is the one modified by the prenominal relative clause, in these examples an object relative. The comma indicates a break in intonation:

83.

- a. Default: N1-ga [[N2-ga ____{N3} V]-N3-o] V
- b. Dislocated: N1-ga ___ V, [[N2-ga ____{N3} V]-N3-o]

The second, dislocated structure (83b) was found to be easier to understand, which Hakuta attributes to the fact that nouns are not concatenated at the beginning of the sentence as in (83a), but rather alternate with verbs. The default order (83a) begins with a noun-noun-verb sequence that in some cases could be initially misparsed as a transitive sentence if the case markers are overlooked, an error which Hakuta's child subjects were apparently making. The results imply that these participants were not using case markers as a cue to structure, but instead relying more on word order alone (Hakuta 1981: 234). The dislocated form, which alternates noun phrases and verbs, does not have a structure that makes it subject to misinterpretation in this way (Hakuta 1981: 224).

These results suggest that clausal center-embedding itself (i.e. the embedded clause being within the main clause and not at the periphery) is not inherently problematic for Japanese-learning children, as long as sequences of concatenated nouns are avoided. As previously mentioned in Section 1.1, Japanese can use word order modifications to avoid center-embedding, but it appears that some center-embedded sentences – those that do not contain a string of subjects – are not significantly harder to process than the default

left-branching, even though the subordinate clause is within the main clause rather than peripheral to it. If the verb of the main clause is moved to follow the subject, producing the order NV [[NV]N], the sentence is more processable even though the embedded clause is still within the main clause, between verb and object.

Hakuta's study used children under age six as participants, and the results imply a strong reliance on word order and less attention to case markers, allowing (for example) two nominative-marked nouns to be misinterpreted as subject and object of the same clause. Whether these observations generalize to adult Japanese speakers is unclear. As explored below in Section 1.4.2.2.4, adult Japanese speakers use case marking as another cue for facilitating processing of center-embedding.

1.4.2.2.2. Mazuka & Itoh (1995): Reading time as a measure of processing difficulty

Other evidence for the general difficulty of center-embedding in Japanese comes from reading-time measures. Mazuka & Itoh (1995: 319) presented the results of an experiment (with adult participants) showing that center-embedded sentences like (84) present more of a real-time processing challenge (as measured by reading time) than control sentences like (85), which contain an equivalent string of proper names with different case markers. In the case of the center-embedded sentences, a slowdown in reading occurs on the second and third nominative-marked names in the string of three subjects, which signal the presence of multiple center-embedded clauses.⁶

⁶ Japanese allows a double nominative construction in which the first NP is understood as the possessor of the second, as in:

Tanaka-san-ga okusan-ga bijin-des-u.

Tanaka-Mr.-NOM wife-NOM beautiful.woman-BE-PRES

'Mr. Tanaka's wife is beautiful.'

However, this construction is not grammatical with two names:

*Tanaka-san-ga Hanako-san-ga bijin-des-u.

Tanaka-Mr.-NOM Hanako-Ms.-NOM beautiful.woman-BE-PRES

*'Mr. Tanaka's Ms. Hanako is beautiful' (Nakamura 2001: 361)

Therefore a sentence like (85) could not be read as a double nominative, and the names marked with -ga could not be understood as part of the same clause.

84.

Yoko-ga Hiromi-o Asako-ni shookaisita
Y-NOM H-ACC A-DAT introduced
“Yoko introduced Hirome to Asako.”

85.

[C1 Yoko-ga
[C1 Y-NOM
[C2 Hiromi-ga
[C2 H-NOM
[C3 Asako-ga kai-ta]
[C3 A-NOM write-past]
genko-o kakina-sita]
draft-ACC rewrite-past]
syorui-o yonda]
papers-ACC read]
“Yoko read the papers that Hiromi rewrote based on the draft Asako wrote.”

Note that in the center-embedded (85), all three consecutive noun phrases bear nominative case, which may cause a slowdown due to similarity-based interference, in addition to whatever processing difficulties are presented by the opening of multiple subject-verb dependencies necessitated by the string of nominatives. The role of case-marking as a factor in the processability of Japanese center-embedding will be discussed more extensively below, in section 1.4.2.2.4.1.

1.4.2.3. Facilitating factors in Japanese

Based on these results, multiple center-embedding seems to present some challenges to Japanese speakers, as it does to speakers of English and other SVO languages. However, some of the same factors observed to facilitate comprehension of center-embedded sentences in English – complement clauses rather than relative clauses as C2 (Section 1.4.2.3.1.1.) subject relative clauses (1.4.2.3.1.2), and avoidance of similarity-based interference, including case marking (1.4.2.3.1.1.) and semantic similarity (1.4.2.3.2.2.) – affect the comprehensibility of center-embedded sentences. An additional factor observed to facilitate processing of Japanese center-embedded sentences is the use of intransitive verbs, and consequent absence

of an object NP, in C3 (Section 1.4.2.3.3.). These results illustrate how both language-particular factors (such as case marking) and language-universal factors (such as preference for subject relative clauses and decreased dependency lengths) influence the processability of center-embedding.

1.4.2.3.1. Clause type

1.4.2.3.1.1. Complement vs. relative clauses

As discussed earlier with regard to English, complement clauses are generally less problematic for center-embedding than relative clauses, because they produce only a long subject-verb dependency, whereas relative clauses additionally require a filler-gap dependency. This pattern also holds true in Japanese. Multiple center-embedding of complement clauses in Japanese is acceptable when the clauses are complements of bridge verbs such as “say” or “know,” as in (86):

- 86.
- [C1 Taroo-ga
 - [C1 Taroo-NOM
 - [C2 Akira-ga
 - [C2 Akira-NOM
 - [C3 Hanako-ga nakidasita
 - [C3 Hanako-NOM started.crying
 - to itta]
 - that said]
 - to omotteiru.]
 - that knows.]
- “Taroo thinks that Akira said that Hanako started crying.”

As Lewis (1996) notes, this observation runs counter to the assumption that all center-embedded sentences containing a string of three subject noun phrases are difficult to process. Note also that in this example, the subjects are all proper names, which would be assumed to create similarity-based interference; however, the similarity apparently does not make this sentence unacceptable. In comparison, a sentence with two center-embedded relative clauses, like (85), appears harder.

In addition, if a center-embedded sentence contains both a complement clause and a relative clause, the placement of these clauses as C2 and C3 affects acceptability.

Babyonyshev & Gibson (1999) addressed this difference through a questionnaire experiment comparing different configurations of clause types in Japanese, i.e. relative clauses within complement clauses (87) or the reverse configuration (88).

87. C2 complement, C3 relative

[C1 Dooryoo -ga
[C1 coworker NOM
[C2 kowai joosi -ga
[C2 strict boss NOM
[C3 raikyaku -ga _ musisita]
[C3 visitor NOM _ ignored]
hisyo -o hihansita to]
secretary ACC criticized that]
itta]
said]

'The coworker said that the strict boss criticized the secretary whom the visitor ignored.'

88. C2 relative, C3 complement

[C1 Kootyoo -ga
[C1 principal NOM
[C2 sensei -ga
[C2 teacher NOM
[C3 syoojo -ga _ tunetta to]
[C3 girl NOM _ pinched that]
itta]
said]
otonasii syoonen -o semeta]
well-behaved boy-ACC blamed]

'The principal blamed the well-behaved boy whom the teacher said that the girl pinched.'

As in English (see Section 1.2.1.1), the combination of a complement clause as C2 and a relative clause as C3 was shown to be more comprehensible than vice-versa. Gibson & Thomas (1998) attribute this to the fact that a relative clause has two dependencies that may be extended by an embedded clause – filler-gap and subject-verb – while the complement clause only has a subject-verb dependency. Thus, the number of lengthened dependencies (and total dependency length) is greater when a complement clause is placed inside a relative clause than vice-versa. This difference is illustrated for Japanese in Figure 1.2.

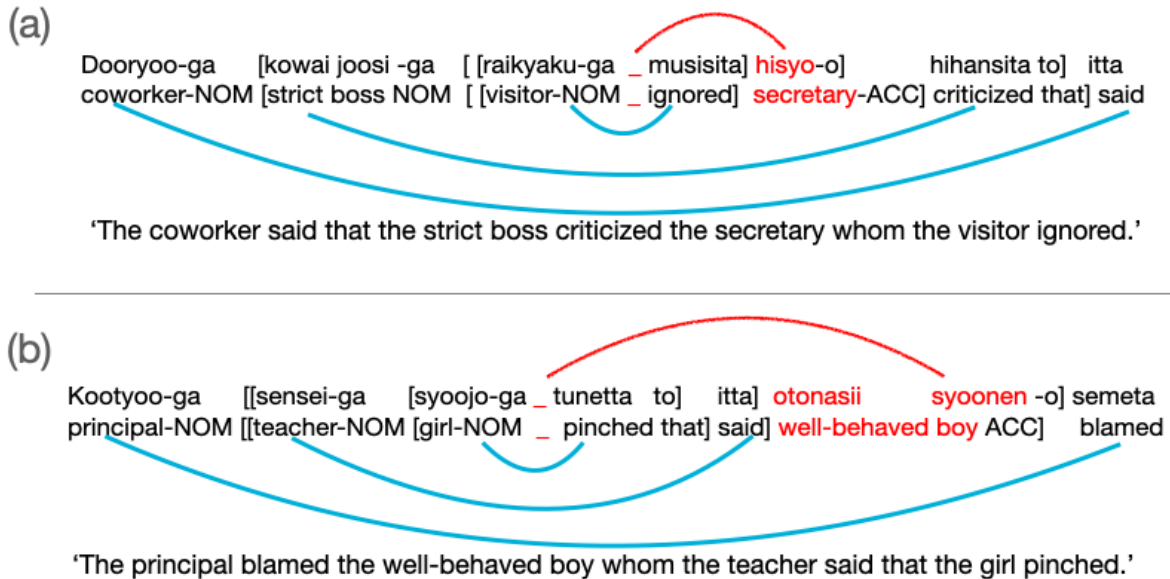


Figure 1.2: Comparison of dependency lengths in a Japanese sentence with a relative clause embedded in a complement clause (a, top) and the reverse configuration (b, bottom). Gap-filler dependencies are in red, subject-verb dependencies in blue. Note the greater length of the gap-filler dependency in b.

In (a) in Figure 1.2, the gap-filler dependency only spans over one word (the verb of C3), but in (b), it must cross over the C3 verb, C3 complementizer, and C2 verb before the filler is encountered. Not only is linear distance greater, but more structural boundaries must be crossed. This means that the processor must wait longer after the gap – which is signalled by the presence of a transitive verb “to pinch” – to retrieve the filler, dealing with the new events introduced by two verbs in the meantime.

1.4.2.3.1.2. Subject vs. object relative clauses

In Japanese as in other languages, subject relative clauses are generally easier to process than object relative clauses, and evidence for this observation comes from reading time measures (Miyamoto & Nakamura 2003) and ERP measures (Ueno & Garnsey 2008). Specifically, a slowdown in reading and electrophysiological evidence of increased processing

(retrieval) load occurred at the head noun following an object relative clause, but not a subject relative clause.

As discussed previously in the context of English (Section 1.2.1.2), this evidence from an SOV language suggests that the generally observed cross-linguistic subject RC preference is due to syntactic structure – how many phrase nodes must be crossed between gap and filler – and not contingent on linear word order, as might be apparent from languages like English. In the case of a language with prenominal relative clauses, like Japanese, the gap in an object RC is closer to its filler in linear distance than in a subject RC, but structural distance is greater (Ueno & Garnsey 2008). (In a language like English with postnominal relative clauses, structural and linear distance are both lower for subject RCs, so the two factors cannot be disentangled.) An illustration is shown in Figure 1.3.

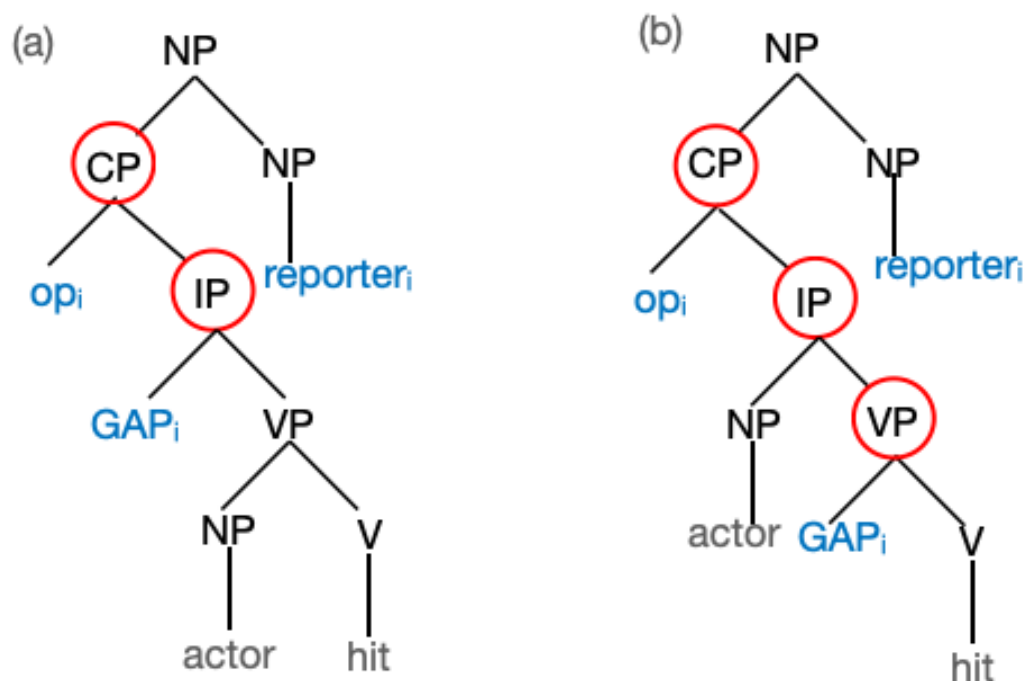


Figure 1.3: Structural distance in subject (left) and object (right) RCs in a verb-final language with prenominal RCs (after Kwon et al. 2006, 2010)

In the case of a subject gap (a), the gap and its filler (“reporter”) are separated by an IP/sentence node and a CP node; however, for an object gap (b), a VP node also intervenes because the gap is located within the VP.

There is an additional factor involved in the processing of center-embedded subject and object relative clauses: the added processing cost of introducing new referents (see Section 1.2.2.1 for this factor in English). In addition to structural distance, another reason that subject relative clauses are easier to process is the lack of an overt subject (as must exist in object RCs). Note, however, that the subject RC in Figure 1.3 still introduces a new referent in object position (“the actor”), so it would still present processing difficulty. As discussed below (Section 1.4.2.3.3) Japanese center-embedded clauses (and clauses in general) are more difficult to process if they include a transitive verb with an object as opposed to an intransitive, so it might be expected that equivalent subject/object relative clauses with a transitive verb (“who hit the actor” versus “who the actor hit”) would be similarly hard to process. In Japanese or other SOV languages, both subject and object relative clauses take the form of an NP followed by a VP. However, if introducing new referents as clausal subjects inherently presents more difficulty than introducing them in other positions, as suggested by Niv (1993), then the subject relative clause (“who hit the actor”) would still be more processable as the only new referent it introduces is an object.

The specific interaction between subject and object relative clauses and multiple center-embedding in Japanese has not been studied. However, given the general tendency for subject RCs to be easier to process (all else being equal), it is plausible that the use of subject rather than object RCs (or other types) facilitates the processing of otherwise difficult examples of center-embedding in Japanese and other SOV languages, as it does in English.

1.4.2.3.2. Noun phrases and similarity-based interference

In Japanese, which has a case-marking system, case markers can produce similarity-based interference, as can the lexical semantic features of the subject noun phrases. When either case markers or lexical semantic parameters (such as being human or animate) are similar across subject nouns, the sentence may become harder to process. Research on Japanese center-embedding has focused considerably on the impact of case-marking, as well as other ways in which noun phrases can be similar or different, and demonstrated that similarity between NPs makes center-embedding harder to process. In the following subsections I discuss two types of similarity that affect processing: case marking and semantic sense.

1.4.2.3.2.1. Case marking variation

There is experimental evidence for the role of similarity-based interference derived from case marking in Japanese center-embedding; i.e. sentences where the subject noun phrases all bear the same case marker are more difficult to process than those with variation in case marking.

Uehara & Bradley (1996), for example, explored the role of identical versus different case marking on Japanese subject NPs in sentences with two center-embedded clauses. They asked Japanese-speaking participants to read these sentences and rate them for comprehensibility. Sentences with the nominative case marker *-ga* on all three noun phrases were consistently rated as more difficult than those with case marker variation, such as the C1 subject bearing the topicalization marker *-wa*. Japanese allows the nominative *-ga* to be converted into the topicalization marker *-wa* for the first noun phrase in the sentence, and *-no* (the genitive marker) for the subject of a relative clause. In (89) and (90), the (b) sentences were rated more comprehensible than the (a) sentences. Processing was facilitated whether the variant case marker was a genitive in C3, or a topic in C1.

89.

a. All nominative

[C1 Keiichi-**ga**

[C1 Keiichi-**NOM**

[C2 ototoo-**ga**

[C2 brother-**NOM**

[C3 ryoosin-**ga** dekaketa]

[C3 parents-**NOM** went.out]

toki kaettekita]

time came.home]

no-ni tomadotta]

fact-at embarrassed]

b. C3 genitive

[C1 Keiichi-**ga**

[C1 Keiichi-**NOM**

[C2 ototoo-**ga**

[C2 brother-**NOM**

[C3 ryoosin-**no** dekaketa]

[C3 parents-**GEN** went.out]

toki kaettekita]

time came.home]

no-ni tomadotta]

fact-at embarrassed]

'Keiichi was embarrassed at the fact that his brother came home when their parents went out.'

90.

a. All nominative

[C1 Satoo-san-**ga**

[C1 Sato-Mr.-**NOM**

[C2 Takahashi-san-**ga**

[C2 Takahashi-Mr.-**NOM**

[C3 sono hito-**ga** Yamane-san-o kokusosita]

[C3 the person-**NOM** Yamane-Mr-ACC sued

to omotta]

that thought]

to itta]

that said]

b. C1 topic

[C1 Satoo-san-**wa**

[C1 Sato-Mr.-**TOP**

[C2 Takahashi-san-**ga**

[C2 Takahashi-Mr.-**NOM**

[C3 sono hito-**ga** Yamane-san-o kokusosita]

[C3 the person-**NOM** Yamane-Mr-ACC sued]

to omotta]

that thought]

to itta]

that said]

"Mr. Sato said that Mr. Takahashi thought that the person sued Mr. Yamane"

Lewis & Nakayama (2001) found further confirmation of this variety of similarity-based interference in Japanese – namely, center-embedded sentences with a single embedded clause and an initial string of multiple nouns become easier to process if the case markers on the subject noun phrases and other arguments are varied. A Japanese sentence with a single embedded clause can have a string of up to five NPs – the subject of C1, a dative object (e.g. the object of a verb like “tell”) and the arguments of the embedded clause, as in (91):

91.

Jon-wa Biru-ni [Mari-ga Suu-ni Bobu-o syookaishita] to itta.
 John-Top Bill-Dat Mary-Nom Sue-Dat Bob-Acc introduced that said ‘
 ‘John said to Bill that Mary introduced Bob to Sue.’

Keeping the number of NPs constant, case marking can be varied to produce more or less interference between NPs, as shown in these abstract examples (92), from Lewis and Nakayama (2001). In both (92a) and (92b), there is one embedded clause, and each clause contributes two noun phrases for a total of four consecutive nouns, but the case marking differs; i.e. (92b) has two nominative arguments in the embedded clause.

92.

- a. [NP-ga NP-ni [NP-ga NP-o V] V]
- b. [NP-ga NP-ni [NP-ga NP-ga V] V]

When there are more NPs with identical case marking, the potential for interference increases; at the point where an NP has to be retrieved, other NPs with the same case marker produce interference, according to the theory of cue-based retrieval (see section 1.2.4). Lewis & Nakayama (2001) carried out a questionnaire study which confirmed this observation, showing that sentences with a string of NPs of this form are easier to process if there are fewer case markers that are the same, creating less interference.

In addition, positional similarity also plays a role in the difficulty of center-embedded sentences, i.e. whether or not adjacent NPs have the same case marking. (93a) is easier to process than (93b) because, while there are two *-ga* case markers, they do not appear in adjacent NPs; rather, a dative-marked NP intervenes.

93.

a. Ani-ga sensei-ni [onna-no-ko-ga asondeiru-to] renrakushita
elder.brother-Nom teacher-Dat girl-Nom playing-that notified
'My older brother notified the teacher that a girl was playing.' (no positional similarity)

b. Haisha-ga [daitooryoo-ga tsuuyaku-o yonda-to] oboeteita.
dentist-Nom president-Nom interpreter-Acc called-that remembered
'The dentist remembered that the President called the interpreter.' (positional similarity)

Scrambling, as mentioned earlier (Section 1.1), can mitigate the difficulty of center-embedded sentences by moving NPs so that ones with the same case marker are not adjacent. Lewis and Nakayama (2001) tested the role of scrambling in another questionnaire experiment in which sentences with a complement clause were presented in default center-embedded order (designated Sso, 94a), with the whole subordinate clause before the main subject (soS, 94b) or with the subordinate clause subject after the subordinate clause object (Sos, 94c) while the clause is still center-embedded. In the default order (94a), there is positional similarity due to the two NPs with *-ga* case markers occurring consecutively; the other orders (94b) and (c) lack positional similarity because the nominative subjects are separated.

94.

a. *Type Sso*

Keikan-ga [ryooshin-ga kodomo-o sagasu-to] kangaeta
policeman-Nom parents-Nom child-Acc look.for-that thought
'The policeman thought that the parents would look for their child'

b. *Type soS*

[Ryooshin-ga kodomo-o sagasu-to] keikan-ga kangaeta.

c. *Type Sos*

Keikan-ga [kodomo-o ryooshin-ga sagasu-to] kangaeta.

Sentences with the entire subordinate clause placed before the main clause subject (94b: soS) were rated the easiest by native speakers, while the other two orders were perceived as harder. Under the assumption that adjacency of noun phrases with the same case marker causes difficulty, it would be predicted that the order Sos (subordinate clause object at the beginning of its clause) would be easier than the default order Sso, because the subject NPs are not strung together, although in both cases the subordinate clause is center-embedded.

However, this order was rated more difficult, which the authors attribute to possible garden path phenomena (e.g. the potential for misunderstanding the subordinate clause object as a main clause object) or the effect of atypical order alone (Lewis & Nakayama 2001: 104). Either of these factors may have overridden any helpful effect of avoiding two adjacent nominative-marked NPs. In any case, the default center-embedded order was judged more difficult than a scrambled order, specifically that which displaces the subordinate clause to the left periphery of the main clause.

In general, both positional similarity (adjacency of noun phrases with the same case) and similarity of case marking across all clausal subjects contribute to the difficulty of center-embedded sentences in Japanese. It is possible to avoid these difficulties by varying case marking, e.g. by topicalizing one subject or changing a relative clause subject into genitive case.

1.4.2.3.2.1. Semantic similarity

In addition to case marking, semantic similarity between noun phrases has been investigated as a possible factor in the processing of Japanese center-embedding, though whether it plays a significant role is unclear.

Nakayama et al. (2005) carried out several experiments with center-embedding in Japanese, and one in Korean (see Section 1.4.3. below for an overview), to explore in more detail the effects of similarity (phonological, morphological, syntactic, and semantic) on processing difficulty. Here I will discuss their Japanese results. The authors tested the role of semantic animacy (i.e. all nouns being animate or human) and found that it did not have a significant effect on the perceived difficulty of center-embedded sentences. Specifically, sentences in which all nouns were animate (95a) were not rated by participants as significantly more difficult than those with a mixture of animate and inanimate nouns (like 95b), with the same clausal embedding structure and sequence of case marking on consecutive nouns:

95.

- a. All animate (humans):
[C1 Kyoju-ga shacho-ni
[C1 Professor-NOM president-DAT
[C2 daihyo-ga kokosei-o shinsasuru-to]
[C2 representative-NOM student-ACC examine-COMP]
yakusokushita.]
promised]
'The professor promised the president that the representative would examine
high school students.'
- b. Mixed animate and inanimate:
[C1 Okusan-ga toshokan-ni
[C1 wife-NOM library-DAT
[C2 otto-ga hon-o yomu-to]
[C2 husband-NOM book-ACC read-COMP]
henjishita.]
responded]
'The wife responded to the library that her husband would read the book.'

As previously noted (Section 1.2.4.), it has been found that semantically confusable noun phrases (e.g. all referring to animals) make English center-embedded sentences harder to process. The apparent lack of such semantic effects in Japanese may indicate that center-embedding is less disfavored in general. In addition (as described in the previous section 1.4.2.3.2.1), the presence of case marking may facilitate differentiation between the NPs concatenated at the beginning of a center-embedded sentence (e.g. the nominative and dative in the above examples) regardless of whether they are semantically similar, effectively eclipsing lexical semantic interference.

1.4.2.3.3. C2 verbs: Transitivity and object NPs

In addition to the role played by case marking, processing of center-embedding in Japanese is also affected by the complexity of C3, specifically the transitivity of the verb. Since transitive verbs require an additional referent within the clause, it stands to reason that they would increase processing difficulty, especially in a verb-final language where they intervene between subjects and verbs. Empirical support for the notion that transitive clauses in Japanese increase processing load comes from the observation that transitive clauses are more likely to

drop subjects than are intransitives (Ueno & Polinsky 2009). Likewise, the impact of introducing a new referent would also be expected to exacerbate difficulties of processing in center-embedded sentences, especially if the new referent occurs in C3, where processing load is already high.

In languages with default SOV order, a transitive C3 in a sentence with two center-embedded complement clauses results in a string of four NPs: three in subject position followed by one object, before any verb appears. This can be seen in previous examples like (90) and is illustrated schematically in (96):

96. [NP1 [NP2 [NP3 NP4 V3] V2] V1]

Babyonyshev & Gibson (1995, 1999) tested the effect of C3 objects in an experiment where Japanese speakers were asked to evaluate center-embedded sentences of this type for difficulty. It was found that sentences with an object in C3 (97a) were more difficult to process than those with an intransitive predicate in the same position (97b):

97.

- a. [C1 Obasan-ga
[C1 aunt-NOM
[C2 bebiisittaa-ga
[C2 babysitter-NOM
[C3 ani-ga imooto -o ijimeta to]
[C3 older.brother-NOM younger.sister-ACC bullied that]
itta to]
said that]
omotteiru]
thinks]
'My aunt thinks that the babysitter said that my older brother bullied my younger sister.'
(Babyonyshev and Gibson 1999).

- b. [C1 Wakai kyooju-ga
 [C1 young professor-NOM
 [C2 TA -ga
 [C2 TA-NOM
 [C3 gakusei -ga konransita to]
 [C3 students-NOM panicked that]
 sengensita to]
 announced that]
 utagatta]
 doubted]
 'The young professor doubted that the teaching assistant announced that the students panicked.' (Babyonyshev & Gibson 1999).

These observations support the general theory that introducing more NPs (with new referents) into embedded clauses worsens the difficulty of center-embedding; in the case of Japanese, increased linear dependency length in C3 is also a factor given that object NPs intervene between a subject and a verb.

1.4.2.3. Conclusion on Japanese

In summary, center-embedding seems to be more permissible in Japanese than in SVO languages such as English, although it is subject to similar processing factors. Japanese also allows word order to be rearranged by scrambling, which can help prevent center-embedded structures, or make center-embeddings easier to process, by avoiding difficult strings of noun phrases. Nevertheless, multiple center-embedding (particularly of complement clauses) appears to be tolerated to a degree that it is not in English or other SVO languages.

Center-embedding in Japanese is also subject to facilitating factors parallel to those in SVO languages, along with some factors not observed or not available in these languages, such as case marking. Specifically, Japanese complement clauses are easier to process than relative clauses, and the complement-C1/relative-C2 configuration easier than the reverse configuration, showing the same effect of increased filler-gap dependency length known in English. There is also evidence that Japanese subject relative clauses are easier to process than object relative clauses, further demonstrating that structural (not linear) filler-gap distance is an important factor

in processing difficulty, although the interaction of this factor with center-embedding has not been well-explored. The existence and flexibility of case marking in Japanese provides another facilitating factor, which may make the center-embedded structures that come about from the default SOV word order easier to process; for example, it is possible to vary case markers and thus decrease interference between several consecutive subject noun phrases. This facilitates the acceptability of even sentences with several descriptive noun phrases (which would be expected to be difficult), and in addition, different case marking on subjects also mitigates the problems presented by semantic similarity across nouns. Avoidance of new referents in C3 also makes center-embedded constructions easier to process, as evident from the easier processing of intransitive over transitive clauses in this position. Despite the striking differences between Japanese grammar and that of SVO European languages, and the fact that multiple center-embedded complement clauses occur with default word order, the same general processing factors can be observed to facilitate comprehension of multiple center-embedding, along with particular language-specific factors.

We now turn to Korean, another SOV language with case marking in which center-embedding has been studied, including comparative studies with Japanese. These two languages show many similarities in how center-embedding can be facilitated or made more difficult, along with some differences that may result from language-specific factors.

1.4.3. Korean

Korean, like Japanese, has SOV default order, meaning that complement clauses are center-embedded by default. It also has prenominal, head-final relative clauses, which means that relative clauses modifying the object of a sentence, but not the subject, are center-embedded under default word order. Korean has case marking, as does Japanese. However, unlike Japanese, relative clauses and NP-complement clauses are marked on the

(clause-final) verb with the adnominal (*-nun* in present tense, *-(u)n* in past tense⁷). These two languages have been the subject of comparative studies with regard to the acceptability and comprehensibility of center-embedding, particularly of complement clauses, and how it is affected by case marking. These findings shed light on how morphological factors affect the acceptability of center-embedding in languages with similar syntax.

In the following sections I will address the general acceptability and difficulty of center-embedding in Korean (1.4.3.1), and facilitating factors (1.4.3.2) including clause type, case marking, referential form, and transitivity.

1.4.3.1. Overview: general acceptability of center-embedding in Korean

As discussed by Suh (2002), Korean is more permissive of center-embedding than English, but some center-embedded sentences can still create processing difficulties. The depth of center-embedding that Korean allows, the processing challenges posed by center-embedding in comparison to left-branching. In the following subsections I will discuss the results of studies and intuitive observations that have examined the general difficulty of multiple center-embedding, and the facilitating factors involved. In Section 1.4.3.1.1. I address the possibility that Korean actually is unusually tolerant of multiple center-embedding, and in Section 1.4.3.1.2. I cover the evidence that center-embedded sentences in Korean present more difficulties than equivalent left-branching constructions. Next, section 1.4.3.2 offers an overview of factors that facilitate the processing of center-embedding in Korean: clause type, case marking, referential form, transitivity of embedded clause verbs, and prosody, with experimental evidence for the role of each one.

⁷ The form *-un* occurs after verbs ending in a consonant, *-n* after verbs ending in a vowel.

1.4.3.1.1. Does Korean allow an unusually great depth of embedding?

There is some tentative evidence that Korean may be highly tolerant of center-embedded constructions that would be difficult if not unacceptable in other languages. Rosenbaum & Kim (1976) reported that sentences with three center-embedded (complement) clauses, such as (98), are judged acceptable in Korean by non-linguist speakers:

98.

[C1 ku moksa-ka
[C1 the minister-Nom
[C2 hananim-kkeyse
[C2 God-Nom(Hon.)
[C3 haksayngtul-i
[C3 students-Nom
[C4 nalssi-ka kay-ki-lul]
[C4 weather-Nom clearup-Gerund-Acc]
palanta-nun kes-ul]
wish-Comp thing-Acc]
kolyehayecwu-si-l]
consider-Hon-Comp]
kes-ul kitohayssta]
thing-Acc prayed]

The minister prayed that God would consider that the students wished that the weather cleared up.'

Note that in (98) the first case marker is an honorific rather than a nominative, and the other case markers show phonological variation. The role of these factors in facilitating processing of Korean center-embedding is discussed below in Section 1.4.3.2.2.1.

However, while Suh (2002) says this sentence is acceptable, there is also experimental evidence that sentences with this level of complexity are difficult for native Korean speakers. For example, Hagstrom & Rhee (1997) showed in a questionnaire study that sentences with three layers of center-embedding are consistently judged more difficult than those with two levels. In addition, center-embedding generally presents more difficulty than left-branching clauses, as explored in the following section.

1.4.3.1.2. General processing challenges: Center-embedding vs. left branching

While Korean may be more tolerant of center-embedding compared to English and Japanese (Rosenbaum & Kim 1976), center-embedding in this language nonetheless produces processing challenges compared to alternative structures. In Korean, since relative clauses are (normally) prenominal, only those clauses modifying main-clause objects are center-embedded within the main clause, while those modifying main-clause subjects are left-branching.

Some findings suggest that even one level of center-embedding – i.e. a prenominal relative clause modifying the object of a verb – creates some difficulty relative to sentences where the prenominal clause modifies the subject (Lee & Stromswold 2007). These examples (99a&b) illustrate the relevant conditions with regard to center-embedding:

99.

a. SS (subject head noun, subject gap)

[yang-ul cidoha-n] yemso-ga tweyci-rul kyekryehaytta
[sheep-ACC teach-COMP.past] goat-NOM pig-ACC encouraged
'The goat that taught the sheep encouraged the pig'

b. OS (object head noun, subject gap)

may-ga [toksuri-rul haychi-n] solgay-rul pwucabatta
hawk-NOM [eagle-ACC hurt-COMP.past] kite-ACC caught
'The hawk caught the kite that hurt the eagle'

Lee & Stromswold (2007) found that reaction time to answer comprehension questions was longer for sentences in which a relative clause modified an object and was therefore center-embedded (99b), than for those in which it modified a subject and was therefore left-branching (99a), with type of relative clause (subject or object) held constant. An additional challenge presented by the configuration in (99b) was a garden path effect – since relative clauses in Korean are not marked at the left edge, the nominative NP followed by the accusative NP in a subject relative clause initially resembles a transitive main clause.

1.4.3.2. Facilitating factors in Korean

In addition to the general difficulty associated with center-embedding as such, there is evidence that Korean center-embedding is affected by facilitating factors that generally parallel those found in other languages.

I discuss the factors that have been studied in the following subsections. Namely, subject RCs are again more acceptable than object RCs as embedded clauses (Section 1.4.3.2.1.); variation in case marking makes center-embedding more processable (Section 1.4.3.2.2.1.); variation in referential form of noun phrases may also contribute to processing by preventing similarity-based interference (1.4.3.2.2.2.); sentences with a simpler C3 (e.g. intransitive rather than a transitive verb) are more acceptable (1.4.3.2.3.); and natural prosody makes spoken center-embedded sentences more comprehensible (1.4.3.2.4.).

1.4.3.2.1. Clause type: subject and object RCs

As in other languages in which this parameter has been studied, subject relative clauses in Korean are more easily processed than object relative clauses. For example, in a self-paced reading task (Kwon et al. 2010), subject-gap relative clauses were read more quickly, with less of a slowdown when the filler noun of the relative clause was encountered. This effect occurred even with supporting discourse context. The stimuli in this experiment employed left-branching clauses modifying the subjects of the sentences, as in the abstract structures shown in (100) (-nun is an adnominal marker):

100.

- a. Subject RC
[GAP Object Verb-nun] FILLER
- b. Object RC
[Subject GAP Verb-nun] FILLER

In addition, Lee & Stromswold (2007) demonstrated that center-embedded subject relative clauses in Korean are processed more easily than object RCs in the same position.

Examples of all four types of clauses used in their stimuli are shown in (101). (101a) and (101b) are not center-embedded, as the relative clause modifies the subject of the main clause, whereas (101c) and (101d) are, because the clause modifies the object.

101.

- a. SS (subject head noun, subject gap)
[yang-ul cidoha-n] yemso-ga tweyci-rul kyekryehaytta
[sheep-ACC teach-COMP.past] goat-NOM pig-ACC encouraged
'The goat that taught the sheep encouraged the pig'
- b. SO (subject head noun, object gap)
[mogi-ga annayha-n] phari-ga nabang-ul chiryoheyatta
[mosquito-NOM usher-COMP.past] fly-NOM moth-ACC treated
'The fly that the mosquito ushered (medically) treated the moth'
- c. OS (object head noun, subject gap)
may-ga [toksuri-rul haychi-n] solgay-rul pwucabatta
hawk-NOM [eagle-ACC hurt-COMP.past] kite-ACC caught
'The hawk caught the kite that hurt the eagle'
- d. OO (object head noun, object gap)
kalmaygi-ga [payco-ga chodayha-n] kiregi-rul tolboatta
sea.gull-NOM [swan-NOM invite-COMP.past] wild.goose-ACC looked.after
'The seagull looked after the wild goose that the swan invited'

Participants were asked to answer multiple-choice questions about each sentence after hearing it, and were assessed on correctness and reaction time. Their results revealed, as expected, that subject relative clauses were more easily comprehended than object relative clauses whether they were center-embedded or not. Furthermore, subject relative clauses that were center-embedded, as in (101c) were actually better comprehended than object relative clauses that were not center-embedded, as in (101b) (Lee & Stromswold 2007: 25).⁸ This

⁸ Double subject constructions with two consecutive nominatives exist in Korean, raising the possibility of a garden path effect in OO type sentences like (101d); however, this construction can only occur with a restricted set of stative transitive predicates as in:

ku salam-i ton-i philyohay
that person-NOM money-NOM necessary,
'That person needs money'(Clancy et al. 1986: 239).

Therefore, it is not likely that a sentence like (101d) would be misconstrued as a double subject, the way (101c) could be initially misunderstood as a transitive SOV main clause.

strong advantage for subject RCs is particularly unexpected given that sentences like (101c) present a garden path effect – the initial string of a nominative NP followed by an accusative NP resembles the argument nouns of a transitive SOV clause – but it is consistent with the cross-linguistic observation that subject relative clauses are generally easier to process (Lee & Stromswold 2007: 34-5). In addition, the authors examined the effects of prosody, which are discussed below in 1.4.3.2.4.

1.4.3.2.2. Noun phrases and similarity-based interference

The facilitating factors described earlier for English (Section 1.2) – e.g. use of pronouns or names instead of descriptive NPs/DPs, or the role of similarity between subjects – have not been examined in as much detail for Korean. However, there is some evidence that similar factors apply. In Korean, as in Japanese, nouns are case-marked, and case-marking can be a source of similarity-based interference. Variation in referential form may also be relevant – and interestingly, in a different way than observed in English.

1.4.3.2.2.1. Case marking variation as a facilitating factor

In Korean, subject nouns bear a nominative case marker. This case marker varies phonologically (it is either *-ka* if the stem ends with a vowel, or *-i* if it ends with a consonant). The nominative marker can also optionally be replaced by a topic marker *-nun*⁹ or an honorific marker *-kkeyse*. Each of these types of case-marking variation is discussed, in the following subsections, and both may serve as facilitating factors insofar as case marker variation lessens similarity-based interference.

1.4.3.2.2.1.1. Phonologically conditioned variation

There is some evidence that phonologically conditioned variation reduces similarity-based interference between case markers, although the strength of the effect is

⁹ Homophonous with some allomorphs of the adnominal marker.

unclear. Consecutive strings of phonologically identical nominative markers, especially on all three subjects, seem to add to processing difficulty.

A questionnaire study by Uehara & Bradley (1996) tested the effect of *i/ka* phonological alternation in doubly center-embedded sentences such as (102). In one condition all three clause subjects were words or names ending with a consonant, so therefore the case markers were identical (102a); in the second, the subject of C3 in (102a) was replaced with one of the same referential form (in this case a proper name) ending in a vowel, so the C3 subject case marker was therefore *-ka* (102b).

102.

a.

All - *i*:

[Sachon-i
cousin-Nom
[Kyengchal-i
police-Nom
[Kiyeong-i wuncensa-lul ttayliessta]
PN-Nom driver-Acc hit
ko cwucanghanta]
that insisted
ko cenhay cwuessta]
that report gave
"My cousin told (me) that the police insisted that Kiyeong hit the driver."

b.

C1/C2 -*i*, C3 -*ka*:

[Sachon-i
cousin-Nom
[Kyengchal-i
police-Nom
[Yengswu-**ka** wuncensa-lul ttayliessta]
PN-Nom driver-Acc hit
ko cwucanghanta]
that insisted
ko cenhay cwuessta]
that report gave
"My cousin told (me) that the police insisted that Kiyeong hit the driver."

They found no difference between sentences like (102a) and those like (102b), both of which were rated as difficult to understand. Note that while C3 has a (phonologically) different case marker than the first two clauses in (102b), there are still two identical adjacent case markers in C1 and C2, which may have caused interference and therefore increased processing difficulty. However, subsequent studies have located an effect, although with sentences that differed along other parameters.

Hagstrom & Rhee (1997) present evidence for a small but significant effect of phonological case marking variation in sentences where the main clause always had a topicalized subject (*-nun*), and the nominative case marking form was varied in the embedded clauses. Sentences of the type in (103b), with different variations of the nominative marker in the embedded clauses, were shown to be slightly easier to comprehend correctly than those like (103a), in which the two nominative case markers in the embedded clauses are the same in phonological form. (Actual examples of the sentences used in the questionnaire are not provided.)

103.

- a. Doubly center-embedded transitive with duplicated case marker
[NP-*nun* [NP-*i* [NP-*i* NP3-*lul* V] V] V]
- b. Doubly center-embedded transitive with different case markers
[NP-*nun* [NP-*i* [NP-*ka* NP-*lul* V] V] V]

Unlike the sentences used by Uehara & Bradley (1996), which had only nominative-marked subjects across three clauses, Hagstrom & Rhee (1997) employed stimuli containing a topic marker in the main clause, only varying the form of the nominative case markers in the two embedded clauses. (103a) still has a string of two identical *-i* nominative case markers, a factor which appears to be a cause of difficulty.

Nakayama et al. (2005) confirmed the effect of phonological case marking variation more clearly, with simpler sentences containing only one embedded clause. For example, in (104a) and (104b) both feature nominative subjects in both the main and embedded clause, but differ in the phonological form taken by the marker on the embedded clause subject NP2.

104.

- a. Identical nominative markers:
[NP1-**ka** [NP2-**ka** NP3-lul V] V]
Euncwu-ka Yengay-ka kyoswu-lul chacawassta-ko kiekhayssta.
'Encwu remembered that Yengay had visited the professor.'
- b. Different nominative markers:
[NP1-**ka** [NP2-i NP3-lul V] V]
Euncwu-ka Hisen-i kyoswu-lul chacawassta-ko kiekhayssta.
'Encwu remembered that Hisen had visited the professor.'

Sentences like (104b), with phonologically different nominative case markers, were found to be easier to process than (104a), in which the case markers are identical in form.

Taken together, these results suggest that an important factor in the processing of center-embedded sentences in Korean, as in Japanese, is avoiding strings of identical case markers on the subjects. All else being equal, Korean phonological variation in nominative case marking may not facilitate the processing of relatively complex sentences (i.e. those with two center-embedded complement clauses), if only the case of C3 is varied. If the casemarking on C1 and C2 is identical, processing seems to be more difficult. Sentences with two center-embedded clauses and three identical case markers also appear to be particularly problematic, since all three subject NPs become confusable and subject to interference.

1.4.3.2.2.1.2. Non-phonological variation

Korean case marker variation that is *not* phonologically conditioned is a clear facilitating factor in the processing of multiple center-embeddings. Specifically, replacing the nominative case marker with a topicalizer (*-nun*) or using an honorific variant (*-kkeyse*) may mitigate the processing difficulty, similar to the Japanese case-marking variation discussed in (1.4.2.2.4.1). This difference is observed by Suh (2000: 287). In (105), all three subjects are nominative, and in addition, their case markers are phonologically identical; according to Suh, this sentence is difficult to process (based on native speaker intuition):

105.

[C1 ku aitul-i
[C1 the kids-Nom
[C2 wuli hyeng-i
[C2 our brother-Nom
[C3 sensayngnim-i o-si-ki-lul]
[C3 teacher-Nom come-Hon-Gerund-Acc]
palanta-nun kes-ul]
wish-Comp thing-Acc]
alkoissta]
know]
The kids know that my brother wants the teacher to come.' (Rosenbaum & Kim 1976)

Sentences like (106), however, are far more acceptable (Suh 2000: 281). In this example, case marking is varied by topicalizing the main clause subject NP (-*nun*) and using an honorific (-*kkeyse*) rather than the usual nominative marker for the C2 subject, producing three different case markers for the contiguous subjects:

106.

[C1 Inho-**nun**
[C1 Inho-TOP
[C2 apeci-**kkeyse**
[C2 father-NOM(Hon)
[C3 Mina-**ka** cikcang-ul olmki-ki-lul]
[C3 Mina-NOM job-ACC change-Nomlz-ACC
wenhasinta-ko]
want-COMP]
malhayssta]
said]
'Inho said that his father wants Mina to find another job.'

This intuitive observation of a difference in processability was experimentally confirmed by Nakayama et al. (2005). In (107a) the first case marker is replaced by a topic marker, whereas in (107b) there are two nominatives that also have the same phonological form.

107.

- a. Topic / nominative *ka*:
[NP1-**nun** [NP2-**ka** NP3-lul V] V]
Euncwu-nun Yengay-ka kyoswu-lul chacawassta-ko kiekhayssta.
'Encwu remembered that Yengay had visited the professor.'
- b. Two nominative *ka*:
[NP1-**ka** [NP2-**ka** NP3-lul V] V]
Euncwu-ka Yengay-ka kyoswu-lul chacawassta-ko kiekhayssta.
'Encwu remembered that Yengay had visited the professor.'

Sentences like (107a) were found to be more processable than those like (107b), confirming the role of similarity-based interference from (non-phonological) case-marking variation. This effect parallels that seen in Japanese, where replacing the main clause subject's nominative case marker with a topic marker makes center-embedded sentences easier to process. A topic marker in the main clause may function to “anchor” the sentence referentially, in the way that descriptive subjects do for complex English sentences (Hofmeister 2011; see Section 1.2.2.1) – a topicalized subject becomes more salient and easier to retrieve when needed, e.g. at a gap or predicate.

In summary, variation in case marking on the clausal subjects in a center-embedded Korean sentence may facilitate processing. Strings of consecutive nominative markers, especially if they are phonologically identical, are hard to process. The sentence becomes more comprehensible if various modifications are made on the case markers, such as using phonologically different nominative markers (particularly avoiding consecutive strings of two or three identical nominatives), topicalizing the main clause subject, or replacing a nominative with an honorific in one clause.

1.4.3.2.2.2. Variation in subject referential form

There is also evidence that the acceptability of center-embedding in Korean is affected by similarity-based interference between subjects, as in English. In addition, processing is facilitated by the occurrence of different referential forms in main and embedded clauses, but in a way contrary to the pattern observed in English (Section 1.2.2.1): *more* specific, not less specific, forms are preferred in embedded clauses and pronouns in main clauses. This may follow from the fact that Korean tends to use zero pronouns, so the presence of an overt pronoun is marked and taken to signal the introduction of a new salient referent.

In Korean, the center-embedding of complement clauses makes it possible for an embedded sentence to begin with a string of subject noun phrases of any type, such as names, which can create similarity-based interference. Suh (2000: 288) observes that (108b), in which the subjects are a name, a definite NP, and an indefinite NP, is more acceptable than (108a), which features four consecutive names, three as subjects and one as C3 object:

108.

a.

[C1 Jina-**nun**
 [C1 J-Top
 [C2 Minho-**ka**
 [C2 M-NOM
 [C3 Inswu-**ka** Swuni-lul ttayli-nun]
 [C3 I-NOM S-ACC hit-Comp
 kes-ul mokkyekhayssta-ko]
 fact-Acc witnessed-Comp]
 malhayssta]
 said]
 'Jina said that Minho witnessed Inswu's hitting Swuni.'

b.

Jina- **nun**
 J-top
 [sensayngnim-**kkeyse**
 teacher- Nom(Hon)
 [kyengchaj-i han haksayng-ul tayli-nun]
 policeman-nom INDEF student-acc hit-Comp
 kes-ul mokkyekhayssta-ko]
 thing-Acc witnessed-Comp]
 malhayssta
 said
 'Jina said that the teacher witnessed the policeman's hitting a student.' (Suh 2000: 288)

There are several possible reasons for why (108b) would be more processable than (108a). First, note also that all of the NPs in (108a) are of the same referential form, namely proper names, and in addition they bear the same nominative case marker, creating similarity-based interference from both referential form and case. As Suh (2000: 289) notes, this makes the opening of (108a) look like an unstructured list of names. On the other hand, (108b) not only features three different case markers, but combines a proper name with two descriptive subjects.

Other experiments have directly tested the effects of different referential forms – i.e. pronouns, names, and descriptive NPs – on processing of Korean center-embedding. Lee et al. (2007) used reading time and eye-tracking measures to examine differences in processing between center-embedded sentences with different combinations of subject types. Their first experiment employed sentences with one embedded complement clause and different combinations of subjects: two descriptive NPs, two pronouns, a descriptive NP in the main clause and pronoun in C2, or a pronoun in the main clause and a descriptive NP in C2. Conditions are illustrated in (109):

109.
 [C1 {Kutul-i / Uysa-**ka** }
 [C1 {3.PL-NOM / doctor-NOM}
 [C2 {wuli-**ka** / haksayng-i } silhum-ul haysstako
 [C2 {1.PL-NOM /student-NOM} experiment-ACC ran
 malhayssta]
 said]
 '{They/the doctor} said that {we/the student} ran experiments'.

Measured reading times were longer, indicating greater processing difficulty, in the conditions where subjects were of the same type, and this effect persisted on rereading. This finding confirms a genuine effect of similarity-based interference between subjects of the same referential form.

There was also a significant difference between the non-match conditions: Sentences with a descriptive NP as a main clause subject and a pronoun as an embedded clause subject (e.g. *the doctor/we*) created more processing difficulty than those with a pronoun main clause subject and a description embedded clause subject (e.g. *they/the student*) (Lee et al. 2007: 509). (The study did not differentiate indexical from third-person pronouns.)

Similar results appeared in a follow-up experiment that used proper names instead of pronouns (Lee et al. 2007: 513-4): similarity-based interference was confirmed, and when the subjects were of different types, sentences with a proper name as main clause subject were

more processable than those with a descriptive NP as main clause subject. Another experiment confirmed that the same patterns held with embedded relative clauses.

Interestingly, these results are contrary to the pattern observed with center-embedded relative clauses in English (see section 1.2.2.1.1, and Warren & Gibson 2002): in English, sentences with more descriptive (less discourse-accessible) subjects in the main clause, and highly accessible subjects like quantifiers or pronouns in embedded clauses, are preferred over those with the opposite pattern. This pattern may be attributed to the fact that Korean is a pro-drop language, i.e. it allows zero subjects and typically uses overt pronouns to mark the introduction of a new topic or focus. In English, by contrast, new discourse referents are typically introduced with proper names, definite descriptions, or other less-accessible referential forms, while pronouns are reserved for referents already introduced into the discourse (see Ariel 2001, Arnold 2010, and Section 1.2.2.1.). Therefore, overt pronouns in Korean have prominence in a way comparable to definite descriptions in a non-pro-drop language like English (see Cowles et al. 2007); i.e. they mark either topic or contrastive focus.

However, the implications of these results for processing differences between Korean and English with regard to referential form are uncertain. As the authors note (Lee et al. 2007: 525), the relevant difference between pronouns/ names and descriptive NPs in Korean is observed early in processing through eyetracking, so it is not clear whether these results are directly comparable to those of English studies such as Warren & Gibson (2002). Warren & Gibson (2002) used ratings of comprehensibility and reading time measures in English, rather than early processing effects, and their theory does not address at what point in processing the effect of referential form should be expected to manifest. Since the English and Korean experiments used different measures as a metric of processing difficulty, it is not certain whether the observed Korean processing differences reflect difficulty in the same way as the English measures. I will return to this apparent difference in facilitating factors between English and Korean in Chapter 2, Section 3.2.2., with regard to relevant corpus data.

To recap, the processing of center-embedding in Korean is facilitated by avoidance of similarity-based interference between subject noun phrases, with regard to both case marking and referential form. In particular, sentences are easier to process when there is a difference between main and embedded clause subjects. In the case of referential form, a center-embedded sentence with a pronoun subject in the main clause and a descriptive subject in an embedded clause is easier to process than the opposite configuration. This is contrary to the pattern observed in English (see section 1.2.2.1.), and reflects the different discourse roles of pronoun subjects in the two languages.

I now move onto another factor involving the introduction of new referents in Korean center-embedded sentences: the acceptability and processability of transitive verbs and their objects in deeper embedded clauses.

1.4.3.2.3. C2 verbs: Transitivity

In Korean as in Japanese, adding an object to a complement clause C3 lengthens the subject-verb dependency within this clause, as well as adding a new referent, but unlike in Japanese this does not appear to make processing of center-embedding more difficult. (110) has two center-embedded complement clauses including a transitive C3:

110.

```

[C1 Sunhi-nun
[C1 S- TOP
    [C2 Chelswu-ka
    [C2 C -NOM
        [C3 Yenghi-ka koyengi-lul cohahan-tako]
        [C3 Y - NOM   cat-ACC   like-that
        malhayss-tako]
        said-that]
    mitnunta]
    believe]

```

"Sunhi believes that Chelswu said that Yenghi likes cats." (Hagstrom & Rhee 1997: 192)

The presence of an object in C3 would both be expected to add to processing difficulty, though there is not clear evidence that such an effect really occurs. In a questionnaire study,

Hagstrom & Rhee (1997) explored the processability of Korean center-embedded sentences in which C3 is a complement clause with a transitive argument structure. As discussed in the previous section (1.4.2.2.5), sentences of this type are more difficult to process in Japanese than sentences with an intransitive complement clause C3.

Hagstrom & Rhee's study also investigated the interaction between the presence of a transitive object with case marking (whether or not phonological variation occurred) and depth of embedding (double or triple). The conditions are illustrated in these schematic examples (111); left-branching control sentences were also used as a baseline:

111.

- a. Doubly center-embedded transitive
NP-Top [NP-Nom-*i* [NP-Nom-*ka* NP-lul V] V] V
- b. Doubly center-embedded intransitive
NP-Top [NP-Nom-*i* [NP-Nom-*ka* V] V] V
- c. Doubly center-embedded transitive with duplicated case marker
NP-Top [NP-Nom-*i* [NP-Nom-*i* NP-Acc V] V] V
- d. Triply center-embedded transitive
NP-Top [NP-Nom [NP-Nom [NP-Nom NP-Acc V] V] V] V
- e. Triply center-embedded intransitive
NP-Top [NP-Nom-*i* [NP-Nom-*ka* [NP-Nom-*i* V] V] V] V
- f. Triply center-embedded transitive with honorific subject
NP-Top [NP-Hon [NP-Nom-*i* [NP-Nom-*ka* NP-Acc V] V] V(Hon)] V
- g. Triply center-embedded transitive with duplicated case and honorific subject
NP-Top [NP-Hon [NP-Nom-*i* [NP-Nom-*i* NP-Acc V] V] V(Hon)] V

As expected, sentences with triple center-embedding were shown to be more difficult than those with double embedding. No significant differences, however, occurred between transitive and intransitive sentences with the same degree of embedding, a result which differs from that observed in Japanese (Babyonyshev & Gibson 1999).

The reasons for this difference between the two languages are not clear, but may involve the presence of other facilitating factors available in Korean but not Japanese. Hagstrom and

Rhee (1997: 201) note that Korean offers more options than Japanese for differentiating case marking on sentences with multiple center-embedding, i.e. phonological variations of the nominative and the honorific marker, and suggest that this provides an additional method for Korean to avoid similarity-based interference on case marking, thus lowering the “overhead” processing cost of center-embedded sentences. Hagstrom and Rhee did not compare all the possible combinations of transitive versus intransitive C3s and different versus identical case markers in Korean; therefore, exactly how these two factors might interact is not well-understood. However, if phonological case marking variation allows center-embedding to be more processable in Korean than in Japanese, as they hypothesize, then center-embedded may be more frequent, and thus speakers would be better able to process complex center-embedding, despite other factors adding to the difficulty. There is some evidence to support theories of this type: I will return to related matters in Section 1.5.1.3 on the role of language-specific variation in the missing VP effect, and in Chapter 2 on the prevalence of naturalistic center-embedding in different languages.

1.4.3.2.4. Prosody

Prosody as a facilitating factor in center-embedding has been explored in English, as discussed previously (Section 1.2.3.), and to a lesser degree in other languages. Two studies (Clancy et al. 1986, Lee & Stromswold 2007) have investigated this factor in Korean, including its interactions with other factors. In both cases, the prosodic factors that were explored included pauses and stresses, contrasting naturalistic prosody with a flat or list-like intonation.

Clancy et al. (1986) performed experiments with Korean-speaking children. Their participants were asked to demonstrate comprehension by acting out a sentence such as (112) with appropriate toy animals.

112.

talamcwi-ka thokki-lul nemettuli-n oli-lul ccochaka-ss-ta
squirrel-NOM rabbit-ACC knockdown-PST duck-OBJ chase-PST-DECL
'The squirrel chased the duck that knocked down the rabbit.'

The sentences that were used contained a relative clause that could be left-branching or center-embedded. In addition, two prosodic conditions were used: naturalistic intonation that was syntactically motivated, or a list-like intonation. Naturalistic prosody produced an advantage in comprehension for center-embedded sentences, which were more difficult to comprehend in general, but not for left-branching ones. The authors take this to imply (for children at least) that intonation is only vital for the comprehension of Korean sentences that cannot be processed in a straightforward left-to-right manner.

Lee & Stromswold (2007), whose work (with adult speakers) was discussed previously in relation to subject and object relative clauses, also looked at prosody as a factor. Their experiments employed two prosody conditions: "high" and "low". These conditions were defined as follows:

For the HIGH Prosody condition, the experimenter prepared the stimuli with longer pauses and stronger stress and intonations than for the LOW Prosody condition, in which the experimenter intended to sound as if he was reading a book out loud rather than engaging in a spontaneous conversation. The HIGH Prosody condition is thus much closer to natural conversational speech in its prosodic character (Lee & Stromswold 2007: 17).

In comprehension tests, "high" prosody improved performance and shortened reaction times for all sentence types, left-branching as well as center-embedded. In contrast to the earlier results of Clancy et al. (1986), this finding suggests a possible role for prosody as a facilitating factor not only for center-embedding but for Korean sentence processing in general. Lee & Stromswold (2007: 37) attribute this difference to the fact that their participants, unlike those of Clancy et al. (1986), were adults: adults do not experience such strong facilitating effects from prosody as children do because their baseline processing ability is higher for these types of

sentences. Differences between the specific prosody conditions, and Lee & Stromswold's use of recorded sentences, may also have played a role. In both experiments, though, it is clear that naturalistic prosody which provides syntactic cues can facilitate the processing of otherwise difficult center-embedded sentences.

1.4.4. Conclusion: Center-embedding in SOV languages

Generally speaking, the syntax of SOV languages permits or requires more center-embedding than that of SVO languages like English; in particular, complement clauses are center-embedded by default. However, with regard to the factors that are known to affect acceptability and processability of multiple center-embedding, some of the same factors appear in both types of languages, along with language-specific factors.

Japanese and Korean are similar to each other in having SOV syntax and case marking, and show similar effects from facilitating factors with regard to center-embedding. For one, complement clauses are easier to process than relative clauses, and the configuration of a complement clause C2 containing a relative C3 is more processable than the reverse, in Japanese. (This specific factor has not been tested in Korean, but it seems plausible that the same pattern would hold.) Second, subject relative clauses are easier to process than object relative clauses (although the interaction with center-embedding has not been tested for Japanese). In both languages, variation in case marking on subjects is another factor that makes sentences with multiple embedded clauses more acceptable; Korean allows case marking variations (namely honorific forms and phonological variation) that Japanese does not, which may account for observations that it is more tolerant of center-embedding. In Korean, the referential form of subjects also affects the processability of center-embedded clauses – specifically, they are easier to process if the subjects of the clauses are different in form, and a subject introducing a new referent to the discourse (which in Korean may be an overt pronoun

rather than an NP) is more processable as a main clause subject than an embedded clause subject.

While SOV languages produce more center-embedding than SVO languages (see Chapter 2 for naturalistic data evidence), similar factors apply to making center-embedding processable, such as the use of different referential forms as main and embedded-clause subjects, and the greater processability of subject relative clauses. Generally speaking, the impact of these facilitating factors, in both SVO and SOV languages, is to decrease the amount of new information in the embedded clauses: for example, subject relative clauses are more processable than object relative clauses because they avoid introducing a new referent in subject position. These universal factors have some relevance to center-embedding in both SVO and verb-final languages, along with language-particular factors.

I now turn to an interesting processing phenomenon – the missing verb phrase effect – and how its existence and variation across languages can further illuminate the factors involved in facilitating or impeding the processing of center-embedded sentences.

1.5. The missing VP effect: Sentences speakers researchers study _ may sound more grammatical without a verb!

An interesting effect produced by sentences containing multiple center-embedded clauses, and one with implications for the processing difficulties involved, is the so-called missing VP or missing V2 effect (Frazier 1985: 178, Gibson & Thomas 1999, Frank et al. 2019). If one of the three required verb phrases for a sentence with doubly center-embedded clauses is missing (113a), the resulting incomplete sentence may be perceived as grammatical – possibly even as more grammatical, more comprehensible, and less complex – than its complete counterpart (113b). This illusion manifests not only in subjective judgments but also in some objective metrics of grammaticality, such as reading-time measures (e.g. Gimenes et al. 2009).

In (113) and subsequent examples V indicates the place of the missing verb phrase, which is generally assumed (as in Frazier 1985) to be in C2:

113.

- a.
[C1 The patient
 [C2 the nurse
 [C3 the clinic had hired]
 V]
met Jack.]
- b.
[C1 The patient
 [C2 the nurse
 [C3 the clinic had hired]
 admitted]
met Jack.](examples from Frazier 1985)

This phenomenon may be categorized as a type of “grammaticality illusion” (Phillips et al. 2011, Ross 2018), in which an ungrammatical sentence seems acceptable, at least on a first reading or hearing without reflective judgment. Such illusions demonstrate what is known as “good enough” processing – the processor takes shortcuts to create a “shallow” low-effort model of a sentence that may not be fully accurate, and then may fail to update representations of the whole sentence (Ferreira et al. 2001, 2002; Christianson 2016). Good-enough processing was first observed with regard to garden-path sentences (Ferreira et al. 2001), which are initially misinterpreted based on an incorrect parse and then reanalyzed. When the sentence is reparsed correctly, semantic information from the previous erroneous parse may be retained and interfere with the “corrected” interpretation (Ferreira et al. 2002). Good-enough processing may also involve incorrect interpretations based on assumed schemas or heuristics. In the case of center-embedding, processing effort might be reduced by not keeping all of the syntactic information in working memory, allowing parts of the structure to be dropped. Interference may also occur as it does in garden path sentences or misinterpretations based on heuristics, and this interfering information must be inhibited for correct parsing. The occurrence of the missing

VP illusion across different languages and sentences with different parameters provides more evidence regarding the factors involved in processing center-embedded sentences, particularly interference effects, along with language-specific factors.

The illusion has attracted considerable attention in research on the processing of center-embedded sentences, though its exact nature and causes are not entirely clear. It is known to occur at least in English, French (Gimenes et al. 2009) and German (Häussler & Bader 2015), although some studies have not replicated the effect in these languages (Vasishth et al. 2010, Fodor et al. 2018). In addition, the effect may not occur in Dutch (Frank & Ernst 2019), and as I will discuss below, its occurrence in German varies based on specific syntactic factors (Bader 2016). This phenomenon is generally thought to result from the processing difficulty of center-embedding, which causes some syntactic material to be dropped from memory, and/or interference effects between possible slots for the verb; in addition, language experience may play a role in whether or not listeners are susceptible to the effect.

In the following subsections I will summarize past literature on the missing VP effect, with attention to the various explanations considered (Section 1.5.1): memory resources (1.5.1.1), interference (1.5.1.2), and language statistics (1.5.1.3.), and the experimental and observational evidence for and against each. Then, in Section 1.5.2, I will address how the missing VP effect interacts with other factors that are involved in the processability of center-embedding, namely prosody and referential form, and consider whether the grammaticality illusion occurs in “easy” sentences as well as ones complex enough to challenge processing resources. Finally I will consider some evidence that the missing-VP effect occurs in production as well as comprehension (Section 1.5.3), and reflect on what the varied occurrence of the illusion across languages implies about center-embedding in general (Section 1.5.4).

1.5.1. Accounts of the grammaticality illusion: What is missing, and why don't we notice?

Various explanations for the missing VP illusion (and its differential appearance across languages) have been proposed, relating to the processing difficulties presented by center-embedded clauses. Two major approaches are resource theories (Frazier 1985, Gibson & Thomas 1999), which explain the missing VP phenomenon in terms of syntactic material being forgotten under high processing load (Section 1.5.1.1), and interference theories (Häussler & Bader 2016, Bader 2016), in which the illusion of grammaticality stems from interference between possible slots for the sentence's final verb phrase (Section 1.5.1.2). In addition, the existence and extent of the illusion appears to vary across languages. For example, while the illusion is well-attested in English, it may not appear to the same degree (or at all), in German and Dutch (Frank et al. 2016, Frank & Ernst 2019), which have mixed head order and allow verb-final clauses. This discrepancy has inspired a third type of explanation: one based on language statistics (1.5.1.3). Most likely, a combination of factors is at work. I will explore each theory and supportive experimental evidence in turn below. The results of experiments involving the missing VP effect are not always directly comparable to each other because different experimental methodologies were used – e.g. subjective judgments versus objective measures from eye tracking or reading time – but they nonetheless show some interesting similarities and differences across languages. The factors that drive the effect, and whether or not it manifests in particular languages or conditions, provide evidence against the resource theory and more strongly support the interference and language-statistics theories.

1.5.1.1. Resource theories

Resource theories propose that the missing VP effect stems from processing load, which causes the parser to simply forget part of the syntactic structure it is building; in this case the forgotten material is the subject noun phrase corresponding to the omitted verb phrase. This

was the earliest type of theory proposed, first by Frazier (1985). A contentious issue for resource theories, and generally concerning the missing VP effect, is which VP is missing in illusionary sentences, since different assumptions imply different underlying causes for the effect.

In this section I will begin by summarizing the earliest formulation of resource theories, known as the disappearing node theory (Section 1.5.1.1.1.). Then I will consider a rival resource theory, structural forgetting (1.5.1.1.2), and later empirical evidence for resource theories in general (1.5.1.1.3). Finally, I will explore evidence that resource theories in general do not provide a full account of the missing VP phenomenon (1.5.1.1.4).

1.5.1.1.1. Frazier (1985): Processing overloads and disappearing nodes

Frazier (1985: 178-9) explains the missing verb phenomenon in terms of processing overload, as follows: the required C2 verb phrase in a sentence like (113) is easily forgotten in processing when the corresponding point in the sentence is reached because at this point, processing resources are overloaded and the C2 subject (“the nurse”) has been semantically combined with other material, i.e. C3 (“the clinic has hired”), so the syntactic information for it is no longer held in working memory while the semantic information is retained. Frazier (1985: 178-9) formalizes this observation with the “Disappearing Syntactic Node Hypothesis”:

At points of high complexity, syntactic nodes will tend to be forgotten if they dominate no lexical material or only dominate material that has already been semantically combined [i.e. has a thematic role or is coindexed with a relative pronoun that has a thematic role].

This account of memory failure follows from the assumptions that constituents of a sentence are preferentially interpreted as soon as possible, and that memory of syntactic information requires active effort. Therefore, when processing resources are strained by complex sentences, the processing system concentrates its limited memory resources on remembering the structure associated with items that have not yet been semantically interpreted – and the syntactic information for items that are already interpreted may be dropped out of memory.

This process can be demonstrated with (113a), repeated here for clarity as (114):

114.
 [C1 The patient
 [C2 the nurse
 [C3 the clinic had hired]
 V]
 met Jack.]

When the processor works through (114), it hits a point of particular processing difficulty at the end of C3. In a sentence with two center-embedded relative clauses, the subject of C3 (“the clinic”) is a locus of particular processing difficulty because after this subject there are five predicted syntactic heads: the main clause predicate, the verb and gap for C2, and the verb and gap for C3 (see Figure 1.4).



Figure 1.4: Dependency chart showing open dependencies at the subject of C3. Filler/gap dependencies are shown above the sentence, subject-verb dependencies below.

Therefore, when the parser reaches the C3 predicate (“had hired”), the DP “the nurse the clinic had hired” is semantically interpreted (i.e. “the nurse” and “the clinic” are interpreted as arguments of “hired”) and “pruned” as soon as possible, leaving no open attachment slot for another verb. Consequently the predicted verb phrase node of C2, the predicate of this entire DP, is forgotten. Then when the C1 predicate “met Jack” is encountered, it is interpreted as the main clause predicate, since there is no open slot in the relative clause. The lack of a C2 predicate therefore gets overlooked and the sentence is considered grammatical.

Frazier's analysis assumes that the missing verb is that of C2, as shown in (113a). However, in (114), "met Jack" is an acceptable predicate for either "the nurse" or "the patient," so the correct analysis might be (115), where the main clause (C1) VP is missing:

115.

```
[C1 The patient
      [C2 the nurse
            [C3 the clinic had hired
                  met Jack ]
            V. ]
```

Gibson (1991) likewise suggests that the main clause verb phrase is the missing one in sentences like (114), and the absence of this verb is overlooked because the main clause subject is the least recent one encountered. This explanation is therefore termed the "least recent node" analysis. The issue of which verb phrase is missing in sentences that produce the illusion is relevant because different missing verb positions would support different explanatory models, as will be explored below.

1.5.1.1.2: Gibson & Thomas (1999): Structural forgetting theory

Gibson & Thomas (1999) point out problems with the previous two hypotheses – disappearing syntactic nodes and least recent nodes – and propose an alternative resource-based theory known as structural forgetting. They find that the previously discussed theories lead to some predictions inconsistent with the observed facts concerning which types of sentences do and do not produce grammaticality illusions.

Frazier's account of disappearing syntactic nodes, for example, predicts that only nodes that do not dominate any lexical material, or which dominate material that has already been semantically combined, can vanish. This would mean that the effect would not apply in sentences with an overt relative pronoun, since this constitutes a lexical element and therefore would prevent its node from vanishing. In fact, the effect does occur with an overt relative

pronoun, as shown by comparing (116) to (113a) – (116) still appears grammatical at first read as does the version without relative pronouns.

116.

[C1 The patient
[C2 who the nurse
[C3 who the clinic had hired
V]
met Jack.]

Another incorrect prediction of Frazier’s disappearing-node theory involves the acceptability of missing-VP sentences where the missing transitive VP, that of C2, is replaced with an intransitive one. If it is assumed that the entire C2 subject (“the nurse who the clinic had hired”) is dropped from syntactic working memory after semantic interpretation, then this omission leaves open a slot created by the first instance of the relative pronoun “who” following “the patient,” at which point the addition of an intransitive VP should be acceptable. This would create a subject relative clause attached to the C1 subject (Gibson & Thomas 1999: 230). In fact, a sentence like (117), in which there is such a misplaced intransitive VP, does not generate the illusion; it is obviously ungrammatical in a way that typical missing VP sentences like (113a) are not:

117. * The patient who [the nurse who the clinic had hired] was smiling met Jack.

Therefore, it is evident that the syntactic information in the C2 subject and C3 is not simply dropped from memory – if it was, then inserting an additional intransitive predicate for “who” would be acceptable. This means that the idea of disappearing syntactic nodes cannot fully account for the missing VP effect.

Gibson & Thomas (1999: 227) propose an alternate resource-based theory that accounts for the scope of the missing VP phenomenon, which they call “structural forgetting.” This concept is based on the capacity theory of Just & Carpenter (1992) and the theories of memory cost established by Gibson (1998), which were summarized in Section 1.2.2.1.1.3. This analysis assumes that when the processor hits the subject C3, a point of high complexity, it

simply forgets whatever syntactic prediction is associated with the highest processing load, a process termed “high memory cost pruning”.

According to Gibson’s (1998) model of verbal working memory, the memory cost of a syntactic dependency is proportional to the number of new referents introduced between the elements of the dependency, in this case the subject and object of a clause. As discussed above, in a sentence with two center-embedded relative clauses, the subject of C3 is a locus of particular processing difficulty where there are five predicted syntactic heads (see Figure 1.4 above): the main clause predicate (which Gibson & Thomas postulate has no memory cost), the verb and gap for C2, and the verb and gap for C3 (Gibson & Thomas 1999: 236). Of these, the C2 verb and gap are the most challenging for processing, since they require holding a long-distance dependency open during the parsing of C3. If C3 introduces a new referent (e.g. “the clinic” in 114), this also contributes to the memory cost. Therefore it is C2 that presents the highest memory cost, which implies that its associated prediction is most likely to be “pruned.”

The memory cost analysis relates to the question of which subject – that of the main clause, C2, or C3 – is being dropped out of memory, and hence which VP is really missing in sentences that generate the illusion. To investigate this question, the authors (1998) performed an acceptability judgment experiment with sentences in which one clause VP was missing and the VPs followed strong selectional restrictions, to avoid any uncertainty about which subject was matched to which VP. These sentences could be complete (118a) or have the C1 (b), C2 (c), or C3 VP (d) missing.

118.

a. All three VPs:

[C1 The ancient manuscript
[C2 that the graduate student
[C3 who the new card catalog had confused a great deal]
was studying in the library]
was missing a page.]

- b. Missing C3 VP:
 [C1 The ancient manuscript
 [C2 that the graduate student
 [C3 who the new card catalog V]
 was studying in the library]
 was missing a page.]
- c. Missing C2 VP:
 [C1 The ancient manuscript
 [C2 that the graduate student
 [C3 who the new card catalog had confused a great deal]
 V]
 was missing a page.
- d. Missing main VP:
 [C1 The ancient manuscript
 [C2 that the graduate student
 [C3 who the new card catalog had confused a great deal]
 was studying in the library]
 V]
 (Gibson & Thomas 1999: 237)

Different versions of the resource theory would predict different results as to which sentences are considered acceptable. Under the disappearing syntactic node hypothesis, all of the VP-omitted sentences (118b,c,d) should be rated as less acceptable than the complete version (118a), because, as discussed above, they have overt relative pronouns – these constitute lexical material and therefore their parent nodes cannot disappear, according to Frazier’s analysis. On the other hand, the least-recent nodes theory suggests that (118d), but not (118b,c), should produce the grammaticality illusion because the main clause subject (the first and therefore least recent in line) would have been dropped. Finally, under the assumption of memory cost pruning, only omitting the C2 VP (118c) should produce the illusion because C2 carries the highest memory cost and would therefore be dropped (Gibson & Thomas 1999: 237).

The results provided support for the pruning hypothesis: sentences with the C2 VP missing (e.g. 118c) were given the same acceptability ratings as equivalent sentences (118a) with all three verb phrases (which is also contrary to Frazier’s assumption that a missing verb

makes a center-embedded sentence *more* acceptable than the complete version). Furthermore, sentences with either the C3 or C1 verb missing (118b and 118d) were rated as less acceptable than either complete (118a) or missing C2 sentences (118c), indicating that they did not produce the grammaticality illusion as sentences like (118c) did. Therefore, the results showed that whatever the exact cause of the missing VP illusion, it only applies to C2.

1.5.1.1.3. More evidence for resource theories: reading time and comprehension

Gibson & Thomas's (1999) experiments used subjective ratings of grammaticality/acceptability as a metric to test the existence of the illusion, but additional studies used more objective measures associated with processability, namely reading time measures and comprehension tests.

Gimenes et al. (2009) carried out a self-paced reading experiment in French using center-embedded sentences with a missing C2 verb. Subjects viewed sentences like (119a) and (119b) on a computer screen, one phrase at a time, with no backtracking (slashes indicate breaks between phrases):

119.

- a. Le plat mexicain/que le critique culinaire/que le magazine a engagé /avait une odeur étrange/

[The Mexican meal/that the gastronomic critic/that the journal hired /had a strange smell/]

- b. Le plat mexicain/que le critique culinaire/que le magazine a engagé/ à goûté dans le nouveau restaurant /avait une odeur étrange/

[The Mexican meal/that the gastronomic critic/that the journal hired/ tasted in the new restaurant /had a strange smell/]

Sentences like (119a) were consistently interpreted as easier to understand than complete ones like (119b) – a stronger result than that of Gibson & Thomas (1999), in which acceptability

ratings for English missing-V2 sentences and equivalent complete sentences were not significantly different. Comprehension questions showed that about half of participants were also capable of sensibly inferring the meaning of the missing verb phrase from the context based on a general schema, e.g., in the case of (119a) above, they would report that the critic ate or tasted the food. However, the reading time for the last VP (that of the main clause) in missing VP sentences was longer than for complete sentences, suggesting a hesitation or slowdown in processing. The reasons for this difference are not clear, but the authors suggest that it may have resulted from a realization that the final verb phrase was not semantically compatible with the subject noun of C2. Alternatively, the difference in reading times could have been a simple position effect, as described by Just & Carpenter (1980): material later in a sentence is read faster, and the final VP comes earlier in a missing-VP sentence than a complete one. The authors interpret the results of this experiment as supporting resource-based accounts of processing – i.e. when the resources required to process a particular phrase become excessive, that phrase is simply dropped, and the sentence is perceived as less complex without it. However, as will be explored in subsequent sections, the resource account is not the only possible explanation for the missing VP illusion, or the one that best accounts for it.

This result also makes sense in light of the attested memory effects of recency and primacy (Andersen 1994, Baddeley 1990, Gernsbacher 1998) – the first and last elements of a list are more likely to be remembered than those in the middle. In this case, the combined effects of recency and primacy (cf. Gernsbacher 1988) make C3 and C1's subjects salient but allow the subject of C2 to be dropped from memory, causing sentences without a C2 verb to appear grammatical. Recency and primacy effects are also relevant to another class of explanation for the missing VP effect which I will discuss later: the interference theories.

1.5.1.1.4: Problems with resource theories

Although Gibson & Thomas's account of structural forgetting covers the data better than Frazier's disappearing nodes theory, resource theories as a whole may not be adequate to explain the missing VP effect. These theories face conceptual problems regarding what they predict about the deletion of specific material, and empirical issues with data from different languages – specifically, the effect does not (always) replicate in German.

One problem raised by resource theories is whether they correctly account for which material can be deleted, or not deleted, in a sentence that generates the grammaticality illusion. Bader (2016: 25) notes that the general conceptual issue with resource accounts is the problem of restricting the theorized process of deletion to only C2. Häussler & Bader (2015) further argue that, under a resource account of parsing that is consistent with general models of working memory, the prediction for the main clause VP is more likely to be dropped from memory than that of C2 because its corresponding subject is the least recent (in keeping with recency effects and the decay of memory traces). However, as reported by Gibson & Thomas (1999) and confirmed in subsequent studies such as Gimenes (2009), it is definitely the C2 VP that is missing in sentences which present an illusion of grammaticality, and omitting other VPs does not produce the illusion; i.e. the resulting sentences are obviously ungrammatical and incomplete (a missing C1 VP leaves a grammatical DP, but not a grammatical full sentence).

In addition, it is necessary to explain why missing VP center-embedded sentences are (sometimes) accepted, but not other sentences, center-embedded or otherwise, with missing obligatory material. Therefore the resource theory predicts too much, and requires stipulations to fit the data. The specific results that the resource theories do predict may not match observed data either. Bader (2016) presents an alternative account, the interference theory, which I consider below.

Another line of evidence that presents a challenge to resource theories concerns the failure of the missing VP effect to occur in some languages. Under a theory involving memory

resources, the effect should be expected in all languages, regardless of specific typological factors, because the same working memory constraints operate. While the effect appears clearly in English and is replicated in French, it may not occur in German, for reasons that will be explored in the following sections.

Vasishth et al. (2010) tested the missing VP effect in English and German with native speakers of each language using quantitative online measures, namely reading time and eye-tracking, rather than subjective judgments of grammaticality. The authors hypothesized that if the illusion was occurring, and therefore sentences with missing verbs were more processable, then reading times for material after the string of verbs (“the judge”) in a sentence like (120) would be shorter in sentences where the C2 verb (“surprised”) was missing, than in sentences with all three verbs. Since the C2 verb is a particular locus of difficulty, removing it would be hypothesized to simplify processing and speed reading times. In (120-121), the verb that was omitted in the missing condition is shown in strikethrough:

120.
[C1 The defence [lawyer]
[C2 who the prosecutor
[C3 that the spy looked at]
~~surprised~~]
convinced the judge.]

The hypothesized effect was seen in experiments with English, confirming that sentences with a missing C2 verb phrase were more processable than their complete counterparts (Vasishth et al. 2010: 543). However, the effect was not replicated in German with equivalent sentences like (121) – i.e., reading times for post-verb material (“den Richter”) in sentences with a missing verb were actually longer than those for sentences with all three verb phrases.

121.
[C1 Der Anwalt,
[C2 den der Zeuge,
[C3 den der Spion betrachtete,]
~~schnitt~~,]
überzeugte den Richter.]

‘The lawyer whom the witness whom the spy looked at ~~avoided~~ convinced the judge’

This pattern of results suggests that complete sentences present less processing difficulty than missing-verb sentences in German, not more as suggested by the predictions of Frazier (1985) and Gimenes et al. (2009) based on English and French. Vasishth et al. (2010) also investigated and ruled out the potential role of language-specific punctuation – German has obligatory commas demarcating finite complement and relative clauses, which may have served as a clear cue to syntactic structure, indicating the presence of subjects that would require predicates. However, rerunning the English tests with the same type of punctuation (optional in English) yielded the same pattern of results as the non-punctuated versions, suggesting that punctuation was not influencing the results. The authors do not consider the possibility that implicit prosody (see Section 1.2.3 on this factor in English) played a role in the processing of these written stimuli; in German, the obligatory commas in writing correspond to obligatory pauses in speech. Therefore, the observed results were taken to reflect more fundamental differences between German and English.

The authors attribute this surprising result to the default word order of German: subordinate clauses can be verb-final, which makes center-embedding more pervasive than in a strictly SVO language like French or English. This therefore means that German speakers have more experience and competence tracking the multiple required verb phrases in a center-embedded sentence than do speakers of languages where basic word order does not readily produce multiple center-embedding (for related issues, see 1.5.1.3 below on language statistics accounts of the missing VP phenomenon, and Chapter 2 on corpus findings).

This apparent variation in the extent and nature of the missing VP illusion across languages is hard to explain under a theory centered on memory resources, which should apply the same way in all languages. Contrary to this assumption, the illusion clearly appears in the SVO languages English and French, but not consistently in German, which is (partially) SOV; nor does it occur in Dutch (Frank & Ernst 2019), as will be discussed below in Section 1.5.1.3.2. Therefore the effect appears to be contingent on typological factors – which would be consistent

with other observations on center-embedding, as I will return to in more detail in Section 1.5.1.3 on “language statistics” accounts. The difficulty of explaining variation in missing VP effects across languages can be mitigated if it is assumed, as Vasishth et al. (2010) do, that the general difficulty of center-embedding is lessened with experience of particular linguistic structures – namely, speakers of languages that allow verb-final order (in some or all clauses) have stronger working-memory representations of predicted verbs because they are accustomed to head-final verb phrases (Vasishth et al. 2010: 558). This would be consistent with the variations between SVO and SOV languages observed in the earlier sections of this chapter, and the corpus results that will be discussed in Chapter 2: SOV languages are more tolerant of center-embedding than SVO languages.

While Vasishth et al. (2010) explain their results in terms of German word order, prosody (in this case implicit prosody in silent reading) may have also played some role in reducing the missing VP effect in German. The obligatory commas between finite embedded clauses in German correspond to prosodic pauses in speech, and electrophysiological research (Steinhauer et al. 2001, 2003) demonstrates that both pauses in sentences read aloud and commas in written sentences produce the same brain response when they indicate a clause boundary. Therefore, the German speakers in this study may have been making use of implicit prosody, as indicated by the commas, to aid in tracking how many clauses had been opened and closed, thereby avoiding the missing VP illusion. I will return to prosody as a possible factor in (English) missing VP illusions below, in Section 1.5.3.1.

I will now turn to another category of explanation for the missing VP effect: interference theories. These follow from the well-known phenomenon of interference in working memory (see also Section 1.2.4 on the role of similarity-based interference in English sentence processing), and may provide an account of the missing VP illusion that better fits the observed data, including data from languages with different word order typology.

1.5.1.2. Interference theories

Interference theories of the missing VP effect have been proposed in response to several conceptual and empirical problems with resource theories of the missing verb effect, as summarized above in Section 1.5.1.1. The phenomenon of interference is well-attested in working memory (see e.g. McElree (2006) for discussion): i.e, the retrieval of information from working memory is more difficult when similar information is present.

Whereas resource theories explain the missing VP illusion by reference to processing overload, interference theories take another approach: they postulate that the illusory grammaticality of missing-VP sentences comes from uncertainty about how to attach the second verb phrase. There are two possible predicted slots available when this phrase is encountered (Bader 2016). The similarity of these slots (i.e. the fact that they both occur at the end of a clause) causes interference and thus mis-attachment of the verb phrase.

An illustration of the predicted verb slots in a partially processed sentence as described by the interference model is shown in Figure 1.5.

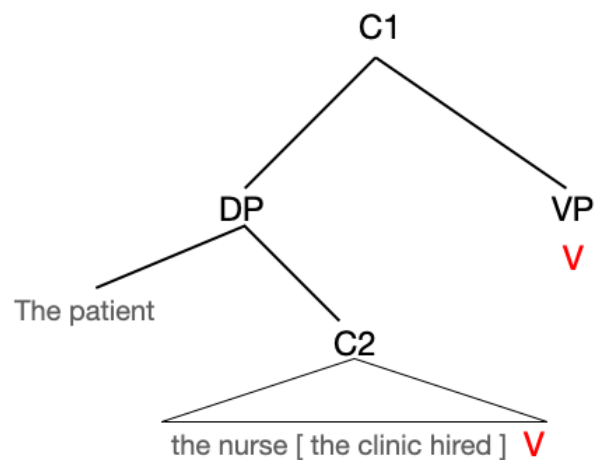


Figure 1.5: Structure of a partial English missing-verb sentence during parsing (after Bader 2016: 25). Two open verb slots (the red V's) remain, one in C2 and one in C1; both are clause-final.

The first verb slot is within the relative clause C2 (“the nurse [the clinic hired] __ ”) and the second in the predicate of the main clause (VP under C1). After C3 (“the clinic hired”) is

finished by the processor, neither of these VPs has been encountered, leaving both slots open. The second slot, corresponding to the predicate of the main clause, is more salient due to primacy (i.e. it was the first verb slot to be predicted, as soon as the main clause subject “the patient” was processed), but this slot and the C2 slot are in similar syntactic contexts (Häussler & Bader 2015). The similarity between these predicted slots produces interference, as predicted by generally known principles of short-term memory (Lewis 1996a), and the parser assigns the remaining VP (“met Jack”) to the slot that is more prominent – that is, to the main clause. The absence of a VP in C2, the less salient slot, is then overlooked.

This interference approach differs from previous models of the missing VP effect in that no syntactic material is assumed to be deleted from memory – rather, the C2 verb is attached to the main clause due to interference between two open (predicted) verb slots and the greater prominence of the main clause slot among them. An intervening clause (C3) between a constituent that needs to be integrated and the required integration site (in this case the subject of C2 and its verb) makes integration of the dependency more difficult (McElree et al. 2003). This is because the first element of the dependency, in this case the C2 subject, loses attentional focus, which makes it more vulnerable to interference from other subjects. This difficulty is compounded in doubly center-embedded clauses in which there are two possible integration sites in structurally identical syntactic positions after completing C3 (see Figure 1.4), namely C2 and C1’s. The higher salience of the main clause C1 means that the lack of a C2 verb phrase can be overlooked.

1.5.1.2.1. Testing the interference theory: Evidence from German

There is empirical evidence to support the interference theory from German (Häussler & Bader 2015, Bader 2016), involving experimental manipulations that affect the salience of the main clause or the similarity between open verb slots. If the C1 clause of a center-embedded sentence is made less salient by making the whole sentence a complement clause, the

sentence may be acceptable with either the C1 or C2 verb phrase missing. These results are discussed in Section 1.5.1.2.1.1.

Another factor relevant for the interference account is the position of verb slots, which can be varied in German, as described in 1.5.1.2.1.2. While the slots for predicted verbs in a center-embedded English sentence like that in Figure 1.4 are syntactically similar – i.e. located at the end of a clause – this is not always the case in German, where the embedded clause can occur in different positions within the higher clause, consequently changing the position of the verb. This means that the interference effect seen in English, stemming from the similarity of main clause and C2 verb slots, need not be present in German. Manipulating this factor creates different results as to the missing VP effect, confirming the role of interference.

1.5.1.2.1.1. Häussler & Bader (2015): Missing verbs in C1 with a superordinate clause

The interference account predicts, according to Häussler & Bader (2015), that the extent of the missing-VP effect should increase if the primacy advantage of the main clause subject is removed. Without primacy, the main clause subject (and verb slot) would be more vulnerable to interference from the subordinate clause subjects (and their predicted verb slots), and this would manifest in the appearance of grammaticality illusions when the main clause VP was missing, as well as the C2 VP.

This hypothesis was tested with the following experimental manipulations on sentences like (122). Grammaticality judgments were compared for sentences in six conditions: all three VPs present, a missing second VP (i.e. that of C2), or a missing final VP (that of C1), indicated in strikethrough text in (122), and each of these types of sentences could be a main clause or embedded in a superordinate clause such as “Ich habe gehört...” (“I have heard...”).

122.

Ich habe gehört

I have heard

[C1 dass seit heute Mittag die Praktikantin,

[C1 that since today noon the intern

[C2 die den Systemabsturz,

[C2 who the system.crash

[C3 der die Technikerin für etliche Stunden beschäftigt hatte,

[C3 which the engineer for many hours occupied had

[VP2 ~~verursacht~~ ~~hat~~],]

caused has]

[VP1 ~~verschwunden~~ ~~ist~~.]]

disappeared.PTCP is]

Complete: "I have heard that the intern who caused the system crash which occupied the engineer for several hours has been missing since noon."

Missing VP2: "I have heard that the intern who Δ the system crash which occupied the engineer for several hours has been missing since noon."

Missing VP1: "I have heard that the intern who caused the system crash which occupied the engineer for several hours Δ since noon."

According to the authors' hypothesis, if a center-embedded sentence (the complete C1-C3 in 122) is placed inside a superordinate clause (*ich habe gehört*, 'I heard'), the missing-VP illusion should occur whether the C2 VP (*verursacht hat*, 'caused') or C1 VP (*verschwunden ist*, 'disappeared') is missing – because the superordinate clause itself takes primacy over C1. On the other hand, if C1 stands alone as a main clause, only the version with the C2 VP (*verursacht hat*, 'caused') missing should generate a grammaticality illusion, whereas a missing C1 VP should be correctly identified as ungrammatical, because of the primacy effect on C1. This result was observed by Bader (2003) for German sentences in a speeded grammaticality judgment task: sentences with either verb phrase missing, and which included semantic and/or syntactic factors that prevented ambiguity as to what exactly was missing, produced the illusion about half the time.

Häussler & Bader (2015) further investigated this phenomenon with two experiments; the first used the same six conditions as Bader (2003) but acquired grammaticality judgments without time pressure. While missing VP effects were weaker than with speeded judgment, the same overall pattern of results emerged. The authors found, as predicted, that sentences with a

missing VP1 (i.e. the C1 verb phrase, *verschwunden ist*, 'disappeared') were more likely to be marked grammatical if the entire C1 was a subordinate clause than if it stood alone as a main clause. No significant difference occurred between the main and subordinate clause conditions when C2 VPs were missing. Finally, complete sentences in both conditions had the highest acceptability ratings of all.

These results are taken by Häussler & Bader (2015) to support the interference account because, in the subordinate clause condition, the "main" clause of the center-embedded sentence – C1 ("*dass seit heute Mittag die Praktikantin...*") as notated above – is less salient than it would be as an independent main clause, and thus its subject is not as robust against interference. Therefore, in this condition the illusion occurs more strongly. This first experiment also confirmed that the missing-VP effect occurs for German in non-speeded tasks, i.e. when subjects are allowed to reflect on grammaticality judgments.

Häussler & Bader's second experiment measured reading time on sentences with a missing C2 VP versus complete doubly center-embedded sentences, where the whole C1 was a subordinate clause, as in (122). It was found that reading times were shorter for the final VP in missing-VP sentences than for complete sentences, suggesting a genuine grammaticality illusion (like that reported by Gimenes 2009) which made the ungrammatical sentences more processable than their grammatical counterparts.

In summary, Häussler & Bader (2015) found that the extent of the missing-VP effect in German is affected by whether the clause C1 is a main or subordinate clause. If C1 is a main clause, a typical missing-VP effect occurs when the C2 VP, but not that of C1, is omitted. However, when the whole C1 is a subordinate clause, it is also possible for a missing VP effect to occur with the VP of C1 – i.e. sentences with this VP missing may be perceived as grammatical. The authors attribute this to primacy effects: specifically, the subject of C1 and its corresponding predicted VP lose primacy and become subject to interference when there is a superordinate clause to take primacy.

1.5.1.2.1.2. Bader (2016): Prefield and middle field clauses

Bader (2016) further details the interference theory, and presents additional experimental results refining the account of Häussler & Bader (2015) regarding how the placement of the center-embedded clause C2 affects the missing VP effect.

The experimental manipulations performed in Bader (2016) involved optional changes in German embedded clause placement. If the higher clause lacks a complementizer, embedded clauses can be placed in the prefield of the clause, i.e., before the inflected verb, which is in verb-second/complementizer position. If there is a complementizer, the embedded clause is placed in the middle field (between the complementizer and the clause-final VP). These two placements are shown in 123(a-b).

123.

a. Prefield in main clause

[C1 Der Polizist,
[C1 the.NOM policeman
[C2 der den Verbrecher,
[C2 who.NOM the.ACC criminal
[C3 der die Bank überfallen hatte,]
[C3 who.NOM the.ACC bank robbed had]
gefasst hat,]
caught has]
wird eine Auszeichnung erhalten.]
will an award receive]

‘The policeman who caught the criminal who had robbed the bank will get an award.’

b. Middle field in main clause

[C1 Vermutlich wird der Polizist,
[C1 presumably will the.NOM policeman
[C2 der den Verbrecher,
[C2 who.NOM the.ACC criminal
[C3 der die Bank überfallen hatte,]
[C3 who.NOM the.ACC bank robbed had]
gefasst hat,]
caught has]
eine Auszeichnung erhalten.]
an award receive]

‘Presumably, the policeman who caught the criminal who had robbed the bank will get an award.’

c. Middle field in embedded clause

In der Zeitung stand,
 In the.DAT newspaper stood
 [C1 dass der Polizist,
 [C1 that the.NOM policeman
 [C2 der den Verbrecher,
 [C2 who.NOM the.ACC criminal
 [C3 der die Bank überfallen hatte,]
 [C3 who.NOM the.ACC bank robbed had]
~~gefasst hat,~~
 caught has]
 eine Auszeichnung erhalten.]
 an award receive]
 'The newspaper said that the policeman who caught the criminal who had robbed the bank will get an award.'

These modifications affect the similarity of the open verb slots, thus providing a way to test the hypothesis of interference between possible attachment points for the verb. Specifically, if the clause C2 is in the prefield, as shown in (123a), then the two verb slots occupy different syntactic positions: that of C2 is clause-final whereas that of C1 is in second position (Bader 2016: 28ff). Conversely, if the clause C2 is in C1's middle field (123bc), then both verb slots are clause-final. This discrepancy implies that sentences with center-embedded prefield clauses will be less subject to interference than those in which the clause is in the middle field, and thus less subject to the missing verb illusion. Differences in implicit prosody, which Bader (2016) does not consider, may also play a role in facilitating processing. Bader (2016) experimentally tested the effect of this difference with six conditions: C2 was placed in the prefield of a main clause (123a), in the midfield of a main clause (b), or the midfield of an embedded clause (c); in each case the C2 verb could be present or deleted. In the examples in (123), verb phrases that were deleted in Bader's missing verb condition are marked in strikethrough text.

This hypothesized result was confirmed. In a grammaticality judgment experiment with German speakers, Bader (2016) found that sentences like (123) with a missing C2 VP were more likely to be accepted as grammatical if the complex relative clause (C2, *der den Verbrecher...*) occurs in the middle field, whether of the main clause (123b) or a subordinate

complement clause (c), than if it is embedded in the prefield of a main clause (a). Specifically, sentences like (123b) and (123c) were found to be more likely to trigger the missing VP illusion than (123a), suggesting that the absence of a verb was more likely to be correctly noticed when the clause with the missing verb was prefield material (i.e. before the inflected main clause verb). There was also no significant difference between sentences like (123b) in which C1 was a main clause, and those like (123c) in which C1 was a subordinate clause; in both cases the center-embedded clause appeared in the middle field. In summary, the missing VP illusion occurred significantly more with midfield than prefield clauses, and was not affected by the presence of a superordinate clause.

Bader (2016) explains this result in interference terms as follows: the verb attachment sites are harder to distinguish if the embedded clause (C2) is in the middle field, because both slots for verbs are in the head of a head-final VP. However, if one verb slot is in the prefield, its syntactic context is different, i.e. it is in second position in a CP rather than head-final. This difference also accounts for the results of Vasisht et al. (2010), in which no missing-verb effect was found for German: their stimuli used only embedded clauses in the prefield (Bader 2016: 12), which would have made the embedded verb slot more salient and therefore less susceptible to interference.

Based on this series of experiments, it appears that the presence of a superordinate clause, as such, is not what influences the grammaticality illusion in German. Instead, the important factor is the placement of the center-embedded clause in prefield or middle field, which determines how syntactically similar the open verb slots are once C3 is completed.

Therefore, in summary, Bader's (2016) theory of interference seems to account well for the English and French data (since in these SVO languages, VP slots are uniformly clause final), as well as the variations observed in German. In the latter, where the syntactic placements of center-embedded clauses can be varied so that the positions of C2 and C3 are not necessarily identical, the missing VP effect appears most strongly in sentences like (123b)

and (123c), which contain two syntactically similar VP slots, suggesting that interference is an important factor.

There are also variations in the appearance and prevalence of the missing VP effect across languages which suggest that universal processing factors, such as memory load and interference, are not the only factors involved. I now turn to some further cross-linguistic evidence and the role of language statistics.

1.5.1.3. The language statistics accounts

A third type of account of the missing-VP effect – not mutually exclusive with the above – looks to language-specific syntactic factors and speaker expectations as an explanation. Resource theories and interference theories would predict that the missing VP effect should appear more or less consistently across languages using syntactically similar stimuli, but this is not what is observed (Vasishth et al. 2010). Therefore it is evident that language-specific properties play some role in incurring or preventing the grammaticality illusion.

For example, German and Dutch may feature center-embedded constructions with strings of three verb phrases (a syntactic phenomenon which I will discuss more in Chapter 2 on corpus studies) more frequently than would a strict SVO language like English; therefore German and Dutch speakers would be more likely to notice when a verb in such a string is missing. This prediction is borne out in experimental observations of the illusion, as detailed below. However, some details of how the illusion interacts with factors of proficiency and language exposure are unclear.

1.5.1.3.1. Vasishth et al (2010): English vs. German

Vasishth et al. (2010) was the first study to compare SVO and mixed headedness languages, namely English and German, respectively, and to show a clear difference in missing VP effects between these languages. As discussed above in Section 1.5.1.1.4, the missing VP effect did not manifest in reading time or eye tracking results in German as it did for English.

Based on these results, the authors argued that the memory factors that cause the missing VP effect are mitigated by reader expectations from specific languages. They suggested that German speakers, compared to English speakers, have more robust representations of predicted verbs in memory, because verb-final structures are more common in German than in English. (Empirical evidence for this idea in natural language usage, regarding strictly SOV languages such as Japanese and Korean, will be discussed in Chapter 2.) However, as discussed above, Häussler & Bader (2016) showed that German missing VP effects are contingent on syntactic variation (i.e. midfield clauses are more subject to the effect due to interference), and suggested that Vasishth et al. (2010) were therefore overstating the difference between German and English in assuming that the missing VP effect did not occur in German.

Further experiments have examined the missing VP effect in Dutch, which has verb-final subordinate clauses as does German, and measured its occurrence in English with L2 speakers whose native languages were Dutch and German. Their results tend to support the language statistics hypothesis: namely, the effect is less robust in German and Dutch than in English, as would be predicted from the properties of these languages. I provide a summary of three relevant studies in the following subsections: Frank et al. (2016) on the effect in German and Dutch L2 English learners, Frank & Ernst (2019) on subjective judgments in English and Dutch, and Frank & Ernst (2021) on eyetracking results comparing native English speakers to L2 learners with varying degrees of exposure and proficiency. Overall, these results confirmed that the effect varies across languages (even within the same speaker), but that shared factors of interference still play a role.

1.5.1.3.2. Frank et al. (2016): German and Dutch L2 English speakers

Frank et al. (2016), using self-paced reading time as a measure, tested for missing VP effects in Dutch, and subsequently in English L2 speakers. In their first experiment, native Dutch speakers did not show evidence of a missing-VP effect with Dutch sentences like (124) involving

two center-embedded subject relative clauses. The verb omitted in the missing-VP condition is here marked with strikethrough text:

123.

[C1 De	moeder	die			
[C1 The	mother	who			
[C2 vrijdag	de	dochter			
[C2 Friday	the	daughter			
[C3 die toen	de	zus	vond]		
[C3 who then	the	sister	found]		
beangstigde]					
frightened]					
begroette	de	oma	op	de	driewieler.] ¹⁰
greeted	the	granny	on	the	three.wheeler.]

“The mother who on Friday frightened the daughter who then found the sister greeted the granny on the three-wheeler.”

Specifically, their reading times were slower for post-C2 material (*begroette de oma...* “greeted the granny”) when the verb was missing than when the sentence was complete. Slower reading times are taken to indicate processing difficulty such as may arise from perceived ungrammaticality, so a slower reading time in a sentence with a missing VP implies that the sentence is not presenting the hypothesized missing-VP illusion, but is correctly perceived as ungrammatical. This result is comparable to what Vasishth et al. (2010) found with German speakers, summarized in the preceding section 1.5.1.3.1.

In a second experiment, Frank et al. (2016) went on to test the appearance of the missing-VP effect in proficient L2 English speakers whose native languages were German and Dutch, with English stimuli. These subjects *did* show a missing-VP effect in English: i.e. slower reading times for post-C2 material in grammatical compared to ungrammatical sentences.

Again, this result is similar to the results seen with native English speakers in Vasishth et al. (2010).

¹⁰ Note that the syntax of this sentence is similar to that of the German prefield clause examples (123a); i.e. the full embedded clause C2 occurs before the inflected verb of the sentence. This should make center-embeddings like this easier than they are in English, for the same reason, i.e. there is less interference between predicted verb slots.

On the basis of these results, Frank et al. (2016) argued that the missing-VP effect is not likely due to working memory constraints alone; if that were the case, it would be observed consistently across languages. Furthermore, if Dutch and German speakers have a more robust working-memory representation of VPs, as proposed by Vasishth et al. (2010), this ability would be expected to carry over to English, but this is not what the results showed (Frank et al. 2016: 567). The authors concluded that the missing-VP effect is caused by differences in the languages themselves, and the expectations that speakers have of them, not by differences in the working-memory requirements for each language. Specifically, the (assumed) higher frequency of multiple center-embedding in German and Dutch compared to English means that speakers have more experience processing these types of constructions and will be more able to notice when a verb is missing – but only in German or Dutch, not English, because they have different expectations for each language.

1.5.1.3.3. Frank & Ernst (2019): subjective judgments by L2 speakers

Frank & Ernst (2019) followed the previous study with an investigation focusing on subjective judgments of sentences (acceptability and comprehensibility), rather than measures of reading time as in previous crosslinguistic studies of the missing VP effect. They noted that subjective judgments are less likely to be sensitive to language statistics than reading times; these judgments are influenced by probabilities that stem from a language's word order patterns (Lau et al. 2017) but also by deliberate conscious thought processes. Therefore, if the missing-VP effect did manifest in subjective judgments by Dutch speakers, this would suggest that language statistics are not the only relevant factor.

This hypothesis was tested by Frank & Ernst in a series of experiments in Dutch and English, with native speaker subjects, using sentences where semantic relationships between DPs and VPs were clear (to avoid any ambiguity as to which VP was missing, as in Gibson & Thomas 1999). Examples are shown in (125). The four conditions used in this experiment were

the same used in Gibson & Thomas (1999): a center-embedded sentence could be complete, or missing any one of its three verb phrases (which are bracketed in 125).

123.

- a. English
 - [C1 The song
 - [C2 that the mother
 - [C3 who the children [scared in the living room]]
 - [thoroughly enjoyed singing]]
 - [was about a lost love]]
- b. Dutch
 - [C1 Het liedje
 - [C2 the song
 - [C2 dat de moeder
 - [C2 that the mother
 - [C3 die de kinderen [lieten schrikken in de woonkamer]]
 - [C3 that the children made startle in the living.room]
 - [heel erg graag zong]]
 - really very gladly sang]
 - [ging over een verloren liefde]]
 - was about a lost love]

In Dutch, all sentences with any verb phrase missing were consistently marked unacceptable or incomprehensible. Complete sentences, with all three required VPs, received the highest subjective ratings of all. The authors also performed a replication of Gibson & Thomas (1999) with English speakers, using translations of their Dutch stimulus sentences. Unlike Dutch speakers, English speakers showed a clear missing VP illusion: they rated sentences with a missing C2 VP as more grammatical and comprehensible than their complete counterparts. Sentences with other VPs missing were rated lower.

A final experiment tested Dutch speakers with high L2 English proficiency. They were asked to provide acceptability and comprehensibility ratings for missing-VP and complete sentences in both languages. In this experiment the subjects showed the missing VP illusion in English, but not in Dutch, i.e. English sentences like (125a) with a missing VP in C2 were accepted as grammatical while equivalent Dutch sentences like (125b) were not. Notably, these subjects did not rate English complete center-embedded sentences as less comprehensible or acceptable than their Dutch equivalents, as would be expected if they simply found

center-embedding more difficult to comprehend in their second language. Therefore, the presence of a missing VP illusion for these speakers in English, along with the absence of this illusion in their native Dutch, cannot be attributed to a lack of English proficiency.

Frank & Ernst (2019) noted, however, that their findings are problematic for an account based primarily on language statistics. For example, since the language statistics account explains the English missing-VP illusion in terms of the rarity of three-verb strings, it cannot explain why the illusion only occurs with the C2 verb missing and not the others. In other words, the language statistics account predicts that some type of missing VP illusion should occur in English, but does not predict the specifics. On this basis Frank & Ernst suggested that the most accurate account of the missing-VP effect would be a hybrid of working-memory accounts (specifically interference accounts) and language-statistics accounts. Considering both cross-linguistic variation and general working-memory phenomena may be necessary to elucidate the specific data observed. In addition, the effect may be related to individual speaker variables, such as proficiency with and exposure to a certain language, and these factors were explored in the subsequent experiment by Frank & Ernst (2021).

1.5.1.3.4. Frank et al. (2021): proficiency and exposure

A more recent study (Frank et al. 2021) addressed English missing VP effects in native English speakers and L2 English learners of varying proficiency levels whose first language was Dutch. This study set out to differentiate between two possible explanations for the occurrence of the effect in L2 English: exposure to language-specific syntactic patterns, and low proficiency.

The authors hypothesized that if the missing VP effect is driven by high exposure to English syntactic patterns, it should be stronger in native English speakers and correlate with exposure in L2 learners. On the other hand, if the missing VP effect is related to low proficiency, then it should be greater in L2 learners with very low proficiency than in native speakers, and vary inversely with English proficiency among L2 learners. (Under this assumption, the missing

VP effect in native English speakers must have another explanation unrelated to proficiency, which makes this account somewhat unparsimonious.) In these eyetracking studies, slowdown and regression in reading were taken to indicate processing difficulty, and the absence of such an effect in missing-VP sentences was taken to mean that these sentences were perceived as grammatical. On these measures, L1 Dutch/L2 English speakers clearly displayed the effect in English. Comparisons between L1 Dutch and English speakers, and within the Dutch group, provided little support for either account: comparison across subjects revealed weak evidence for an increase in missing-VP effects with English exposure, and no clear evidence for a decrease in missing-VP effects with English proficiency.

The robust occurrence of the missing verb effect among native English speakers, of course, suggests that exposure to English grammatical patterns plays an important role. Language statistics are likely one factor but not the whole explanation; for example, interference effects may also be involved across languages. I will now discuss some ways in which the missing VP effect might interact with, or be affected by, other factors involved in the more general processing of multiple center-embedding.

1.5.2. The missing verb effect in relation to other factors

The abovementioned studies on the missing verb effect, its appearance in different languages, and its possible causes have looked at the effect largely in isolation – without much attention to how it might interact with other factors that facilitate or worsen the comprehension of center-embedded sentences. The stimulus sentences used are generally the most difficult sort of center-embedded sequence, in which the subject NPs/DPs and VPs of embedded clauses are semantically complex. In the next section I turn to research that addresses the interaction of the illusion with prosody (1.5.2.1) and other facilitating factors, and also point out some factors which have not been as thoroughly explored (1.5.3.2).

1.5.2.1. Prosody

As discussed in section 1.2.3 of this chapter, prosody is also relevant to the processing of center-embedded sentences (Fodor and Nickels 2013, Fodor et al. 2017, 2019), and the difficulty of fitting complex center-embedded sentences into a prosodic pattern may also be involved in the missing verb effect. As explained by Fodor and Nickels (2013), the verb phrase in C2 may be separated from C3 by a prosodic break (shown as || in 126) if the whole C2 is too long to fit into a prosodic phrase, and if this happens, the parser may fail to integrate that VP back into the sentence.

126. NP1 || [_{C2} NP2 [_{C3} NP3 VP3] || VP2] || VP1

This raises the question of how the missing VP effect may be either triggered or mitigated by phrase length, which influences prosody. Fodor et al. (2017) took up this question, comparing the missing V2 effect in sentences with “encouraging” and “discouraging” clause lengths as in (127). To recapitulate, an “encouraging” pattern is one in which the C1 main clause subject and predicate are long enough relative to the entire embedded C2 to allow the sentence to break into three prosodic phrases, and a “discouraging” pattern is one in which the C1 main clause subject and predicate are shorter, and C2 longer, making this prosodic pattern harder to achieve.

127.

a. Encouraging Complete:

The rusty old ceiling pipes
that the plumber
my dad trained
fixed
continue to leak occasionally.

b. Encouraging Missing:

Admittedly, the rusty old ceiling pipes
that the plumber
my dad trained
V
continue to leak occasionally.

c. Discouraging Complete:

The pipes
that the unlicensed plumber
the new janitor kindly assisted
tried to repair
still leak.

d. Discouraging Missing:

To no-one's surprise, the pipes
that the unlicensed plumber
the new janitor kindly assisted
V
still leak.

Unexpectedly, they found that participants consistently marked sentences with a missing VP as unacceptable in both prosodic conditions (encouraging and discouraging); no clear grammaticality illusion occurred regardless of prosody. The reasons for this failure to replicate the missing VP effect, which is generally observed in English with comparable sentences, remain to be clarified. In addition, prosody (including implicit prosody) likely plays a role in the processing of center-embedding and specifically the missing VP effect in other languages (see Section 1.5.1.2.1 above), and it has not been well-explored.

1.5.3.2. Other factors

The missing verb phenomenon is evidently triggered by the same factors that generally contribute to the difficulty of center-embedded sentences: processing overload and/or interference between similar syntactic elements, plus prior language experience. This raises the question of whether it occurs with “easy” center-embedded sentences, namely those with features that facilitate processing. The sentences used to illustrate or elicit missing VP effects (like most used in center-embedding studies) are typically long and complex, featuring semantically specific definite description subjects that introduce new referents, and two center-embedded object relative clauses (to generate a string of three VPs). Following Gibson’s (1998) theory that the difficulty of center-embedded sentences is exacerbated by the addition of new referents, it would be predicted that sentences where the embedded clause subjects do not introduce new referents (e.g. they are indexical pronouns) would be less prone to the illusion. As explored in Section 1.2.2.1.1.3, this theory is supported by experimental results for comprehension and measures of difficulty, but it has not been tested specifically with regard to the missing VP illusion. However, to my judgment, (128a) and (129a) sound obviously incomplete with not even an initial short-lived illusion of grammaticality such as occurs in “classic” missing VP cases:

128.

- a. *The woman someone I know _ exited
- b. The woman someone I know brought exited. (Kluender 1992)

129.

- a. *Sentences people you know _ are more likely to be accepted.
- b. Sentences people you know produce are more likely to be accepted. (De Roeck 1982)

(“Departed” is used as the main clause verb for (128) since “left” in this context could be misinterpreted as transitive in the sense of “abandoned”, producing a grammatical determiner phrase.) In response to (128a) spoken aloud, one informant initially thought that “someone I know” was meant to be an appositive (i.e. “the woman, [who is] someone I know, exited..”), but on reflection agreed that “something is missing” from the sentence. Informants also notice that something is ungrammatical in (129a), and on reflection, realize that the missing element is a verb. It appears, therefore, that the illusion of grammaticality is weaker or less persistent in these sentences than in more typical examples.

These sentences have a variety of facilitating factors of the type discussed in Section 1.2. Of the three subjects in (128), two are pronouns (one indefinite and one indexical), and (129) features the bare plural “people” and an indexical pronoun in C3. The C3 verb in both, “know” is also stative, another possible factor making processing easier. This means that the strings of DPs/NPs and VPs probably do not overload processing as in the more complex and difficult examples typically used in experimentation, such as the very long stimulus sentences from Gibson & Thomas (1999).

However, I do perceive an illusion of grammaticality, as do other native English speakers I have consulted, if any non-final VP is removed from (130), as in (130b-d), a previously discussed sentence from Bever (1974), which pushes the limits of acceptability. This does not happen if the main clause VP is deleted as shown in (130a); this sentence is obviously

incomplete, to my perception – it can stand alone as a (grammatical but very complex) DP, but not as a full sentence.

130. [C1 The pictures
 [C2 a reporter
 [C3 everyone
 [C4 I met ____]
 trusts ____
] took ____]
 showed that arson caused the fire.]
- a. The pictures a reporter everyone I met trusts took V
 - b. ??The pictures a reporter everyone I met trusts V showed that arson caused the fire
 - c. ??The pictures a reporter everyone I met V took showed that arson caused the fire
 - d. ??The pictures a reporter everyone I V trust took showed that arson caused the fire.

Despite its “easy” C4 clause (“I met”) and the universal quantifier “everyone” as C3 subject the level of embedding in this sentence causes difficulty and makes it harder to spot when any verb in an embedded clause is missing. These are intuitive observations, however, and would need to be backed up by more formal experimentation.

If the missing VP effect is related to the difficulty of integrating the dependencies of C2 (filler and gap, subject and verb) on either side of C3, then it is not surprising that the illusion is weakened if the C3 is simplified, reducing the memory load the processor must carry while a dependency is open, nor that the illusion can manifest if C3 itself has an embedded clause C4, as in (130). Further research is needed to clarify whether and how the missing VP effect interacts with factors that can make center-embedded sentences easier.

1.5.3. Missing verbs in production: German, English, and Italian examples

The missing verb effect is apparent in production as well as in comprehension, although there is relatively little research on this topic. In a corpus study of center-embedding and missing verbs in German, Bader (2015) located several examples of center-embedded sentences with missing verb phrases, such as (131):

131.

Ebenso ist der Herr Jesus Christus,
likewise is the lord Jesus Christ,

[der hier mit vollem Titel
[who.NOM here with full.DAT title

[der Seine ganze Größe und Herrlichkeit andeutet,]
[which.NOM his entire greatness and glory indicates]

V]

V]

die Quelle von Gnade und Friede.
the source of grace and peace

‘Likewise is the Lord Jesus Christ, who here [...] with His full title, which indicates His whole greatness and glory, the source of grace and peace.’

Bader (2016) observed that this missing VP effect never occurred in extraposed clauses, but only in center-embedded clauses that are in situ like (130), where the burden on memory is higher due to the open dependencies. Missing VPs are also much more common in center-embedded clauses in the middle field (12 out of 54 found examples) than embedded clauses in the prefield (2 out of 89). Bader (2016: 19) attributes this discrepancy to the same factors which influence the strength of the missing VP illusion in comprehension (see Section 1.5.1.2.1.): the relative rarity of missing VPs in prefield clauses, and their more frequent occurrence in midfield clauses, is consistent with the assumption that missing-VP effects are fostered by interference between similar verb slots, which is present if the clause is embedded in the midfield but not if it is embedded in the prefield. General processing factors also play a role: the prefield is a sentence-peripheral position, and thus material here is easier to process because it does not intervene within open dependencies. Likewise, extraposed clauses are more processable than embedded ones as they are also peripheral to the sentence, on the right rather than the left edge, meaning they can be processed without the additional burden of open dependencies from the main clause. As discussed in Section 1.1 of this chapter, extraposition of clauses is one way languages avoid deep center-embedding, especially of “heavy” constituents that would otherwise create prohibitively long dependencies between subjects and verbs.

There is also some (anecdotal) evidence of this effect in production in English and Italian. The following examples of missing VPs (132-4) in written center-embedded clauses are of my own observation, and I will discuss how each of these complicated sentences may have generated a missing verb effect due to factors that could increase its difficulty.

132.

I only remember the bit in Garfield 2
 where the animal staff of the castle
 [C2 that the spoiled nobleman cat
 [C3 that Garfield has been switched with]
 V]
 doesn't know how to make lasagne...
<https://forums.somethingawful.com/showthread.php?threadid=3910844&userid=0&pagenumber=1709#post513487199>

The missing verb phrase in (132) is probably “owns” or “lives in” (i.e., the nobleman cat owns the castle). With the complex definite description subjects “the animal staff of the castle” and “the spoiled nobleman cat,” and similarly long predicates, along with the object relative clause C3, this sentence features several of the factors known to make center-embedding difficult, so it is not surprising that a verb phrase has gone missing.

In (133), the missing verb occurs within a preposed adverbial clause (“when the native...”) in which another fairly long and complex subject relative clause (“who caught...”) is embedded, and that relative clause itself contains a (right-branching) non-restrictive modifying relative clause (“that thrived...”):

133.

Since the days
 [C2 when the native Ohlone people,
 [C3 who caught and ate the bounty of oysters and abalone and crab
 that thrived throughout the bay,]
 V]
San Francisco has been a good place for seafood. (Jurafsky 2014: 35)

Here, the missing verb phrase was probably “lived here.” C3 is quite long and complex despite being a subject relative clause, which may account for the disappearance of the verb phrase of C2. The author may also have misremembered or misconstrued the initial clause as “Since the

days of the native Oholone people,” which would not require a verb phrase. It is possible that multiple production-related factors, not strictly related to the difficulties of center-embedding, may be involved in examples like this.

Another missing-VP sentence (134) was found in a corpus search for multiple center-embedding (described in more detail in Chapter 2), this one from Italian. It appeared as a result for the search pattern due to faulty tagging:

131.

```
[C1 il fatto
[C1 the fact
    [C2 che una persona
    [C2 that a person
        [C3 che va-da in discoteca ]
        [C3 who go-SBJV to disco ]
    ]
    _____ ]
    implich-i ]
    imply-SBJV
        che questa si drogh-i è una fesseria ...
        that this.FEM REFL drug-PRES be-PRES a nonsense
```

“The fact that a person who goes to the disco [V2] implies that they do drugs is idiotic.”

This sentence presents the common and relatively processable complement C2/subject relative C3 configuration, but with a missing VP in C2. Here, the predicate for the C2 subject *una persona* “a person” is missing. A native Italian speaker has confirmed that the sentence seems grammatical at first read, but breaks down on examination when it becomes apparent that a predicate is missing, specifically that of C2 (I. Caponigro, personal communication).

It is interesting to note that all of these examples occurred in writing – two in informal internet conversation, the other in a printed book – so the writers would have been able to recheck their work. The two English examples (132-133) are the sort of center-embeddings that create difficulty in comprehension, featuring complex definition descriptions as subjects, such as “the bounty of oysters...” and “the animal staff of the castle.” While the Italian example (134) features multiple facilitating factors – a complement clause C2 and a subject relative C3 – the depth of embedding is still potentially conducive to production error. The existence of missing

VP errors in production seems more compatible with a forgetting account than an interference account – i.e. the speaker or writer simply forgets about a previously uttered or written subject. However, either interference or structural forgetting, or a combination of both, could explain why these errors survive proofreading.

1.5.4. Conclusion: The grammaticality illusion and its implications

Whatever its precise causes (structural forgetting, interference effects, and/or language expectations), this peculiar grammaticality illusion testifies to the processing difficulties posed by (some) center-embedded sentences, and the role of language-specific as well as general factors. Several different explanations, which are not mutually exclusive, have been proposed. While the earliest theories, which were based on assumptions of limited memory resources and consequent structural forgetting, did not account well for the observed data, later analyses concerning interference between similar predicted verb slots and experience with different languages are more robust. However, the presence of the missing VP effect in production – i.e. genuine written examples of center-embedded sentences with C2 missing – may be more compatible with a structural forgetting account. In addition, the same factors that facilitate or worsen general comprehension of center-embedded sentences, including prosody, likely contribute to the missing VP effect. The illusion appears across multiple languages (at least English, French, and German, which are reasonably closely related), but does not always replicate, for reasons that can sometimes be accounted for syntactically (as in the results of Vashisth et al. (2010) on German, discussed in the previous sections 1.5.1.2 and 1.5.1.3, on interference and statistical accounts). In addition, the illusion may or may not occur with easily processable sentences, i.e. those possessing such facilitating factors as indexical, pronoun, or indefinite subjects in the embedded clauses, which confirms that it is triggered or exacerbated by processing difficulty. Double center-embedded sentences with a missing C2 VP have also been observed in production in several languages, which lends support to the idea of structural

forgetting, despite the deficiencies of this account for explaining the perceptual illusion. On the basis of all this experimental and observational evidence, it seems likely that a variety of processing factors are involved in the effect and its varied occurrence across languages.

While the missing VP effect is known to vary in occurrence and prevalence across European languages with different word orders, namely English and French versus Dutch and German, it is not known whether it appears in languages with strictly SOV order, such as Japanese and Korean. Bader (2016: 9) suggests that the missing VP effect would still be expected to occur in strictly head-final languages, but the evidence from Dutch and German suggests that the prevalence and strength of the effect are in fact mitigated by head-final order. Under the plausible assumption that SOV order makes center-embedding more prevalent and therefore more tolerated (which is confirmed based on corpus results, as discussed in Chapter 2), it is likely that Japanese and Korean speakers would not show missing VP effects in their native language, or only demonstrate the illusion with extremely difficult sentences.

Another largely unexplored area of interest is how the missing VP effect interacts with, and may be prevented by, other factors that affect the processability of center-embedded clauses. Prosody is another possible factor which may be relevant even in experiments with written stimuli (due to implicit prosody in reading), but has not been well-explored. Most research so far – like most research on center-embedded sentences generally – has focused on very complex stimulus sentences with definite subjects and long verb phrases. One factor which has not been well-explored is prosody, which is potentially a factor in the German observations – commas in the written language correspond to obligatory prosodic pauses in speech, and therefore implicit prosody (see Section 1.2.3.) may facilitate the comprehension of complex sentences in written form. I have already noted that simplifying the intervening subjects appears to weaken the grammaticality illusion when the C2 verb is dropped. This may be due to the simplicity of the subjects per se and/or due to a reduction in similarity-based interference.

1.6. Concluding thoughts: center-embedding across languages

All of the typological and experimental evidence discussed so far suggests that while center-embedding presents processing difficulties, its acceptability, processability, and prevalence (the range of structures that can be center-embedded, and the allowed depth) vary across languages. Research into both facilitating factors and the missing VP effect confirms this supposition. While similar factors and phenomena generally hold across languages – e.g. semantically and referentially "lighter" clauses and subjects are easier to embed – syntactic typology also plays a role.

As reviewed in Section 1.1., languages have multiple syntactic methods for avoiding center-embedding, but these are tendencies rather than universals – e.g. sentences with a degree of embedding that would be unacceptable in one language may be fully acceptable in another. The subsequent sections reviewed experimental and observational research on the factors that make center-embedding harder or easier to process in various languages: English in 1.2, other SVO languages in 1.3, and two SOV languages (Japanese and Korean) in 1.4.

These studies reveal many similarities among the factors that facilitate processing of center-embedded sentences. Generally speaking, center-embedded sentences are easier to process when the embedded clauses introduce fewer new referential elements and fewer long dependencies. These criteria are reflected in the types of center-embedded sentences that are easier to process: for example, complement clauses are more processable than relative clauses because they lack a gap, and subject relative clauses are more processable than object relative clauses because they do not introduce a new discourse referent as subject. Perhaps the clearest evidence of this “avoid new referents” principle comes from findings on the role of referential form, discussed in Section 1.2.2.1 for English. There is also some evidence that semantically nonspecific nouns (e.g. “people,” “things”), verbs without tense, and simpler lexical aspects in embedded clauses may facilitate processing, because they avoid introducing new semantic information. Besides these factors involving specific syntactic and lexical features, the

overall length of clauses, and thus the prosody with which they can be produced, influences processing – sentences in which syntactic boundaries correspond to prosodic breaks are easier to parse. Finally, another factor that affects the processability of center-embedded sentences is the widely observed working memory phenomenon of similarity-based interference. Prosody and interference effects hold across the languages for which they have been studied (English, Japanese, and Korean).

However, some interesting differences across languages, based on syntactic and morphological factors, also appear. For example, there is some evidence (discussed in Section 1.3.) that speakers of Romance languages are better at comprehending complex center-embeddings in their own languages than are English speakers. The reasons for this are unclear but may involve some combination of more flexible word order and richer agreement morphology, which make speakers of these languages less exclusively reliant on word order cues for parsing.

More striking, however, are the differences between SVO and SOV languages. Japanese and Korean, due to their default word order, permit or require center-embedding in contexts where it does not occur in SVO languages, particularly multiple complement clauses. Nonetheless, center-embedding in these languages is susceptible to comparable factors of new referents and interference, even if the “baseline” acceptability of multiple embedding may be greater.

Additional evidence for cross-linguistic differences in the processability of center-embedding comes from the occurrence and prevalence of the missing VP illusion, explored in Section 1.5. Experimental evidence shows that this effect occurs fairly reliably in English, and possibly in other SVO languages; i.e. doubly center-embedded sentences with a missing C2 VP are mistaken for grammatical and more easily processed than complete versions. Its occurrence in mixed-head-order languages (German and Dutch) is more variable, which strongly suggests that the effect is contingent on language-specific properties. In

particular, the existence of permitted or obligatory word orders that produce center-embedding (in this case verb-final clauses) may make center-embedding actually more common in natural discourse, therefore making speakers less susceptible to the illusion because they are more accustomed to processing sentences of this type.

We would expect this apparent cross-linguistic difference, and the relevant facilitating factors, to be reflected in real-world usage of center-embedding, and I have already offered some qualitative evidence for the role of these factors in the form of observed examples. The following chapter takes a more quantitative approach by way of a cross-linguistic corpus study, comparing languages with different basic word order, and examining some of the observed facilitating factors in the results.

Chapter 2. Center-embedding in the wild: Cross-linguistic corpus data and observed examples

In Chapter 1 I focused primarily on experimental results concerning the factors that facilitate acceptance and processing of center-embedding, along with qualitative observations of acceptability and attested examples (e.g. De Roeck et al. 1982, Sampson 2001). However, these results and observations do not provide a complete picture of how frequently, and to what extent, the phenomenon of interest occurs in normal language use. I have set out to explore this question, with attention to syntactic typology, by searching corpora of multiple languages for center-embedded patterns. In addition, I have analyzed the sentences found through the corpora – along with many examples observed in English – with regard to some of the facilitating factors discussed in Chapter 1.

The organization of this chapter is as follows: In Section 2.1, for background, I offer an overview of the existing corpus studies on center-embedding, and their limitations. Direct comparisons of the actual prevalence of center-embedding across languages are limited, and it is not clear how the frequency center-embedding varies with respect to basic word order since the existing studies primarily focus on European and SVO languages. As discussed in the previous chapter (Sections 1.1 and 1.4), verb-final languages are more conducive to multiple center-embedding, and therefore would be expected to allow more frequent center-embedding in natural discourse. My own corpus study, covered in Sections 2.2-3, sets out to address this problem and explore the prevalence of known facilitating factors in attested examples of center-embedding. Section 2.2.2 presents the methodology used to search the corpora and the quantitative results by language and typology, and I show based on these results that multiple center-embedding is significantly more prevalent in verb-final languages than in languages with SVO or mixed order. I also address the issues of whether and how inflectional morphology affects the prevalence of center-embedding, and the presence of multiple center-embedding in

speech. In these cases the results are less clear because the data is limited, but it appears that languages with richer inflectional morphology (the Romance languages) do not have a significantly higher rate than English, and that multiple center-embedding may be very rare in speech. Finally, in Section 2.2.3., I examine some of the corpus search results (Appendix A) along with my collection of 146 observed English examples of multiple center-embedding (Appendix B), with regard to several of the facilitating factors observed in Chapter 1: clause type, subject type (across languages, and in English and Korean specifically), and case marking in Japanese and Korean.

2.1. Overview of previous corpus work on center-embedding

While occasional discoveries of multiple center-embedding “in the wild” are informative because they weaken the assumption that center-embedding is hard to process, such one-off observations do not necessarily mean that center-embedding is abundant or widely accepted. Consequently, more systematic corpus research is required to address the question of how center-embedding might differ in prevalence across languages, and how this prevalence relates to differences in basic word order and other linguistic factors. In this section I will provide an overview of existing corpus research as a lead-in to a new study across multiple languages, with attention to how the prevalence of center-embedding appears to be affected by syntactic word order parameters.

Corpus studies focusing specifically on center-embedding are limited, and most do not present robust comparisons across languages. It is generally evident, however, that multiple center-embedding is uncommon across the languages and discourse types that have been studied, and is especially rare in spontaneous speech, but more frequent in writing. In addition, as I show in Section 2.2.3, there is evidence center-embedding is uncommon compared to equivalent right-branching and left branching dependencies. Existing studies, however, are

limited to mostly European languages with SVO order, instead of covering languages with different basic word orders.

The organization of this section is as follows: first I will discuss studies on text corpora, (Section 2.1.1), then studies on spoken language corpora (Section 2.1.2), then studies presenting comparisons between center-embedding and other constructions (Section 2.1.3), and finally I will address the limitations of these existing corpus studies (particularly with regard to the languages covered) and the questions they leave open, which have motivated my own study (Section 2.1.4).

2.1.1. Text corpora

Of the few corpus studies specifically focusing on center-embedding, most of them employ text corpora and involve European languages, particularly German and English. The results generally suggest that multiple center-embedding is uncommon, and sentences with more than two center-embedded clauses nearly nonexistent in writing. In addition, there is evidence that the prevalence of center-embedding varies with genre and style.

The earliest corpus study to address center-embedding explicitly was Korthals (2001), which investigated center-embedded relative clauses within a small German newspaper corpus. In this corpus of ~20,000 sentences, 13 double center-embeddings were found. Relative clauses were about three times more likely to be extraposed than center-embedded, which is consistent with the general observation that center-embedding poses particular processing difficulty, and that extraposition is a way to avoid it (see Section 1 of Chapter 1 on general cross-linguistic trends). Other clause types, e.g. complement clauses, were not analyzed in this study.

Karlsson (2007) performed a more extensive study of clausal center-embedding (including complements, relative, and adverbial clauses) in seven European languages: English, French, German, Finnish, Latin, Swedish, and Danish. The data consisted of two large English

corpora – the Brown corpus and Lancaster-Oslo-Bergen corpus – plus descriptive surveys of the other languages, and incidental observations of sentences in naturalistic texts. These large corpora were searched for sentences with multiple WH-elements or subordinators, which were then manually analysed. 132 total sentences with multiple center-embedding were found. In these results, the estimated incidence of two-level center embedding, across English corpus samples, was about .02%, or one sentence in 5000. Most of Karlsson’s complex center-embedded structures involve relative clauses. One commonly seen configuration (15 of 132) was a relative clause inside a complement clause such as (1), a structure which, as discussed in Section 1.2.1, is known for being relatively easy to process.

1.

[C1 The idea
 [C2 that everyone
 [C3 we deal with _]
 is straight]
 is classified as heterosexism.] (from Karlsson 2007c).

Note also the other facilitating features of this example: the quantifier subject *everyone* in C2 and the indexical pronoun subject *we* in C3. I will further discuss the appearance of these factors in my own observed examples of center-embedding in Section 2.3.

Subsequent corpus searches have generally confirmed the intuition that multiple center-embedding is uncommon in natural language, even in writing. Bader (2016: 19) performed a search of the German deWac corpus (Baroni et al. 2009) for center-embedded structures, including those with missing verbs, as discussed in Chapter 1, Section 5. In a sample of approximately nine million sentences, only 163 doubly center-embedded sentences were found, suggesting a very low rate of multiple center-embedding (~ 1 in 55,000).

While generally uncommon in writing, center-embedding may be more prevalent in certain genres that are highly technical and describe complex ideas. Martinez et al. (2022), as part of a study on factors which make legal contracts difficult to process, found that English contracts have a much higher rate of (single) clausal center-embedding than other text genres:

75% of sentences in the contracts had at least one center-embedded clause, while other genres showed 35% or less. This study did not cover multiple center-embedding, but its results suggest that some variation across genres is possible.

To summarize, the existing corpus studies suggest that multiple center-embedding is fairly rare in written language (at least in English and German), but it may be more common in certain technical and formalized genres, such as legal writing, than in more colloquial genres such as journalism. I now turn to what research exists on center-embedding in transcribed corpora of spoken language.

2.1.2. Spoken corpora

Besides the aforementioned research on text corpora, there are a few studies of center-embedding in corpora of spontaneous speech, and the general consensus that emerges is that center-embedding is even rarer in speech than in writing. This reflects the generally simpler syntax of spontaneous speech. Compared to written language, spontaneous spoken language generally features less clausal subordination (Miller & Weinart 1998: 22) and fewer and simpler relative clauses (*ibid*, 157-8). This observation lends support to Karlsson's (2007) prediction that center-embedding would be rare and limited in speech, even more so than in writing, which is well-confirmed by the few corpus studies that exist.

The relevant studies discussed here cover two SVO languages (Finnish and English), one SOV language (Japanese), and one with mixed headedness (German), suggesting that center-embedding may be uncommon in informal spontaneous speech regardless of syntactic typology. However, as I will discuss, the analysis of syntax in spontaneous speech is not always straightforward. The apparent examples of center-embedding in spontaneous speech which are observed may not be true instances of center-embedding, but are amenable to alternative analyses involving anacoluthon (a mid-sentence change in grammatical structure), WH-movement, or parenthetical comment clauses (Karlsson 2020).

Laury & Ono (2010) analyzed small corpora (about 1000 clauses each) of Finnish and Japanese telephone conversations, and found no unambiguous cases of multiple center-embedding. The authors note (Laury & Ono 2010: 74) that spontaneous speech cannot always be analyzed clearly into sentences or even clauses, which makes it difficult to identify true center-embedding. In addition, there are constructions in Finnish and Japanese that can be analyzed either as clausal subordination or quotative particles (which mark the preceding sentence as a quote). For example, Japanese *ttsuta* in (2) is a contraction of a quotative complementizer *te* and the past tense verb *yutta* “said,” and therefore could be classified as either a subordinator or a quotative marker:

2.
 [shumi de yatten no ka] ttsuta-ra...
 hobby as doing NMNL Q say-COND...
 ‘When (I) said ‘are (you) doing it as (a) hobby?’...
 (NMNL = nominalizer, Q = question particle, COND = conditional)

However, even under a generous definition of embedding, i.e., consistently interpreting ambiguous structures such as the quotative in (2) as clausal, no examples of multiple center-embedding appeared in these small corpora of spontaneous conversation.

When center-embedding does occur in speech, it may be limited to more formal registers (just as it may be more common in more formal and technical varieties of writing). In a corpus study of transcribed spontaneous speech in public and non-public settings, Verhoeven & Lehmann (2018) demonstrated that the rate of center-embedding also differs between formal and informal registers of speech. Center-embedding (of clauses and DPs) is overall very rare in German speech, and much less common than right-branching for the same structures. However, center-embedding was found to be more prevalent in formal public speech (e.g. political debates) than in private conversations; this reflects a general trend for higher syntactic complexity in formal settings.

In a larger-scale study, Karlsson (2020) further addressed the question of whether, and to what extent, center-embedding occurs in spontaneous spoken language. Through an

analysis of several large corpora of spoken English, including the British National Corpus and the Pear Stories corpus, Karlsson turned up very few instances of two-level center-embedding. (3) is one of very few attested examples of clear double center-embedding in speech; note that the C3 (“I won”) features an indexical pronoun subject, a known facilitating factor as discussed in Section 1.2.2.1:

3. It’s ironic that I’m here,
 [C1 where the man
 [C2 the trophy
 [C3 I won]
 is named after]
 coached.]

However, there are some methodological difficulties at hand. The grammatical analysis of transcribed spontaneous speech is not always clear, especially using transcripts that do not provide clear prosodic information (Miller & Weinart 1998: 12). Some apparent instances of center-embedding may in fact be the result of processes such as anacoluthon, a mid-sentence shift in grammar. Karlsson (2020) discussed the following example as a potential double center-embedding:

4. I mean like I said to quote the example again of Debbie who said, when
 describing both a woman she didn’t like and a man she didn’t like the very first
 quality she didn’t like was uhm weak

This utterance can be analyzed as featuring two levels of center-embedded clauses (5); C2 is a time adverbial clause inserted between “said” and its complement, and C3 is an object relative modifying the first conjunct of the DP “a woman... and a man.”

- 5.
- ...Debbie
 [C1 who said
 [C2 when describing both a woman
 [C3 she didn't like]
 and a man
 she didn't like]
 the very first quality
 she didn't like
 was uhm weak ...]

However, Karlsson (2020) suggests that another, more plausible, analysis is possible. This analysis involves a mid-sentence anacoluthon (grammatical shift), and is shown in (6). In this case, the sentence breaks off after the second instance of “she didn’t like,” which forms part of a parallel pair of right-branching structures, and the speaker then breaks off and embarks on an entirely new sentence (S2, “the very first quality...”):

- 6.
- [S1 Debbie
 who said,
 when describing both a woman
 she didn't like
 and a man
 she didn't like –]
 [S2 the very first quality
 she didn't like
 was uhm weak]

Therefore, this supposed example of spoken multiple center-embedding must be considered marginal.

Some other examples that Karlsson (2020) observes are also amenable to an alternative analysis that does not represent true multiple center-embedding, such as C3 in (7):

- 7.
- [C1 and people on the basis of the voluminous reading
 [C2 which
 [C3 I know]
 you've all done _]
 are invited to uh ask the speaker questions]

While (7) superficially looks like an instance of double center-embedding, Karlsson (2020) suggested that sentences like this actually feature “relatives Raised from lower clauses over reporting verbs, thereby epiphenomenally making reporting expressions like *everybody thinks* and *I’d like* center-embedded.” That is, these sentences feature the strings of subjects and verb phrases typical of center-embedding, but the actual syntax is not center-embedded in the same way as examples like (3), in which one relative clause is actually embedded inside another. (8) is an alternative analysis of (7) with the C3 (“you’ve all done [the reading]”) analyzed as a right-branching complement clause for C2’s “know,” from which *which* undergoes long-distance WH-movement to precede *I know*:

- 8.
- [C1 and people on the basis of the voluminous reading₁
 [C2 which I know
 [C3 you’ve all done _₁]]
 are invited to uh ask the speaker questions]

Karlsson (2020) also noted that some instances of what appear to be short center-embedded clauses such as *as I say* and *I know, if you like*, and *that is*, but which are amenable to a different analysis as non-integrated parentheticals. An example is shown in (9):

- 9.
- [C1 A particularly striking feature of the report
 [C2 which
 [C3 as I say]
 we commissioned in nineteen eighty-eight]
 is the growth in coverage in manual occupations.]

In (9), C3 (“as I say”) may be a comment clause, which Karlsson (2020) defines as a “metatextual, idiom-like” discourse element that is not structurally integrated into the main clause. Comment clauses may function as hedges and are typically set off by pauses in speech and commas or parentheses in writing. (See also Kaltenbock (2007) on parentheticals, of which comment clauses are a type, and Aijmer (1997) on English *I think* as a modal particle.) The

short C3 in (9) is likely a comment clause, and similarly C3 (“I know”) in (7) could also be analyzed as such if it was bracketed by prosodic pauses, indicated by commas in (10b):

10.
 - a. ... which I know you’ve all done (complement clause as in (8))
 - b. ...which, I know, you’ve all done (parenthetical comment clause)

In Karlsson’s analysis, parentheticals and comment clauses are not considered true center-embedding, so (9) is not a real example of multiple center-embedding and (7) may not be either. (7) is also not a true case of center-embedding if analyzed as the result of long-distance WH-movement, although it superficially bears a center-embedded structure (three subjects and then three predicates). Therefore, apparent examples of center-embedding from corpus findings must be scrutinized for false positives. Based on the written and spoken corpus evidence, Karlsson (2007, 2020) concludes that center-embedding tops out at three levels in written language, and two in speech, and that these maxima are quite rare.

2.1.3. Evidence for the particular difficulty of center-embedding

Overall, based on the observations summarized above, it is clear that multiple clausal center-embedding is disfavored in spontaneous speech, and to a lesser degree in writing and formal speech. However, as noted by Legate et al. (2014), corpus counts of center-embedding (or other rare syntactic phenomena) are not necessarily meaningful without context on the frequency of center-embedding relative to other syntactic structures. Therefore, it is informative to compare center-embedding to multiple dependencies in other forms.

There is evidence to suggest that the dispreference for center-embedding is not a reflection of a general bias against multiple dependencies, as far more extensive dependencies can occur in right or left-branching form. Karlsson (2010), based on quantitative data, noted that sentences with as many as eight right-branching clauses are attested in corpora, and sentences with 3-5 such clauses are common. This contrasts sharply with the apparently strict and rarely seen upper limit of three center-embedded clauses which Karlsson (2007, 2010) also observes.

Verhoeven & Lehmann (2018) also found right-branching clauses with depths of up to six in spontaneous speech in German corpora, again in contrast to the rarer and limited appearance of multiple center-embedding.

Further general evidence for the particularly limited nature of center-embedding, as opposed to other dependency forms, comes from Blasi et al. (2019), a corpus study of clausal subordination in 17 languages. It was found that deep clausal embedding – encompassing both branching and embedded dependencies – was not disfavored in written language, and very long chains of dependencies (as many as 20 clauses) appear. These findings suggest that clausal dependencies in general may be effectively unlimited, but that center-embedding in particular is restricted.

2.1.4. Limitations of previous studies

While these corpus studies are valuable, they are limited in linguistic scope. Of Karlsson's languages, five (English, French, Finnish, Danish, and Swedish) have primarily SVO order. Latin has flexible word order but is predominantly SOV, while German features mixed headedness: it is underlyingly SOV, but in clauses without overt complementizers the inflected verb appears in second (V2) position, and all phrasal categories are otherwise head-initial. No strict SOV languages (such as Japanese or Korean) were included. In addition, all of Karlsson's languages belong to the Indo-European family, with the exception of Finnish, and four are Germanic languages (English, German, Danish, and Swedish), the latter three of which moreover all have V2 structure in clauses lacking overt complementizers. Therefore, Karlsson's sample is low in typological and genetic diversity. The actual prevalence of center-embedding across different languages, as a result, remains somewhat unclear, as does its relation to word order typology. Based on the typological observations discussed in Section 1.1, it might be expected that verb-final languages would actually permit more center-embedding in natural discourse. On the other hand, however, the supposed difficulty of multiple center-embedding

might mean that these languages avoid such complex sentences through extraposition and other word order arrangements. The present study sets out to answer these questions empirically with real-world data.

As Karlsson (2020) notes, searching for center-embedding in corpus data is not straightforward: center-embedded structures can take various forms, and some are not always readily searchable, such as relative clauses without overt relative pronouns, or complement clauses with zero complementizers. Therefore, the approach of Karlsson (2007), namely searching for sentences with multiple WH-elements, could fail to find genuine examples and thus underestimate the overall prevalence of center-embedding. However, finding the structures of interest is more feasible with certain types of tagged corpora or treebanks, which also offer more extensive multilingual data. For this purpose the Universal Dependencies (de Marneffe et al. 2021) set of corpora is particularly useful. UD explicitly tags dependency relations, thus making it simple to search for a pattern of dependencies that are nested within dependencies of the same type (e.g. subject and verb). These corpora form the main source of the following cross-linguistic corpus study.

2.2. Center-embedding across languages in Universal Dependencies corpora

2.2.1. Methods: the search pattern and the languages analyzed

Selected corpora with Universal Dependencies tagging were searched by means of the grew-match interface (<http://universal.grew.fr>), using the search pattern (11):

```
11.
pattern {
  V -[nsubj|nsubj:pass]-> N;
  V2 -[nsubj|nsubj:pass]-> N2;
  V3 -[nsubj|nsubj:pass]-> N3;
  N << N2;  N2 << N3; N3 << V3;
  V3 << V2; V2 << V;
}
```

This specifies the existence of three subject-verb dependencies (passive subject-verb dependencies are tagged separately so they must be included as an alternative), in nested order, forming a classic center-embedding configuration: N1 N2 N3 V3 V2 V1. The general dependency structure is illustrated in Figure 2.1. from Bever (1970), in which the arcs are subject-verb dependencies:



Figure 2.1: Subject-verb dependencies in a doubly center-embedded sentence, matching the search pattern used in this study.

All available corpora for the following languages were searched:

SVO: Danish, English, Finnish, French, Italian, Spanish, Swedish

SOV: Japanese, Korean, Latin, Persian, Turkish

Mixed: Dutch, German

Together these corpora contain a total of 712,492 sentences. All found sentences were then examined to remove false positives (e.g. those resulting from incorrect syntactic tagging), with the assistance of linguists who were fluent speakers wherever possible. Also included in the analysis of facilitating factors (2.3) were 138 English sentences observed in books, online, et cetera, with multiple clausal center-embeddings, some of which have been presented and discussed earlier in the paper. The full lists of all analyzed corpus sentences, with glosses, are collected in appendix A; English found sentences are in Appendix B.

2.2.2. Results

In this overview of the results by language, I will discuss the following findings: the prevalence of center-embedding according to syntactic type (Section 2.2.2.1), the hypothesis that languages with richer inflection are more permissive of center-embedding (2.2.2.2), and

tentative evidence for the extreme rarity (but not absence) of center-embedding in speech (2.2.2.3). One pattern that clearly emerges is that center-embedding is substantially more common in verb-final languages (with the exception of Persian) than in those with other basic word orders. The role of inflection is less clear, as SVO languages with richer inflection than English have similarly very low rates of center-embedding. Finally, based on the limited spoken-language corpora available, center-embedding in speech appears to be rare or nonexistent, although I can attest one personally observed example.

2.2.2.1. Prevalence of center-embedding by syntax type

Tables 2.1-3. provide the number of sentences per language with double (or more) clausal center-embedding (CE), after exclusion of false positives, across syntactic types and languages. An (S) indicates spoken corpora.

Table 2.1. Universal Dependencies results for SVO languages

Danish		CE	Total
	Danish Dependency Treebank	0	5512
	All	0	5512

English		CE	Total
	Airline Travel Information (S)	0	5432
	Georgetown University Multilayer	0	9130
	ParTut	0	2090
	Parallel Universal Dependencies	0	1000
	LinEs	0	5243
	English Web Treebank	1	16621
	All	1	39516

Table 2.1. Universal Dependencies results for SVO languages, continued

Finnish		CE	Total
	Turku Dependency Treebank	0	15136
	Parallel Universal Dependencies	0	1000
	FinnTreeBank	1	18723
	OOD	0	2122
	All	1	35723

French		CE	Total
	ParTUT	0	1020
	GSD	0	16431
	Sequoia	0	3099
	French Question Bank	0	22890
	Parallel Universal Dependencies	0	1000
	French TreeBank	0	18535
	Rhapsody(S)	0	2806
	Paris Stories(S)	0	1761
	All	0	46812

Italian		CE	Total
	Italian Stanford Dependency Treebank	0	14167
	Venice Italian Treebank	0	10087
	ParTut	0	2090
	TWITTIRO	0	1424
	PoSTwita	1	6712
	Parallel Universal Dependencies	1	1000
	Valico	0	398
	MarkIt	0	800
	All	2	37173

Table 2.1. Universal Dependencies results for SVO languages, continued

Spanish		CE	Total
	AnCora	1	17680
	GSD	0	16013
	Parallel Universal Dependencies	0	1000
	All	1	34693

Swedish		CE	Total
	Talbanken	1	6026
	Lines	0	5343
	Parallel Universal Dependencies	0	1000
	All	1	12369

Table 2.2. Universal Dependencies results for mixed head order languages

German		CE	Total
	Hamburg Dependency Treebank	5	189928
	GSD	1	15590
	Parallel Universal Dependencies	0	1000
	LIT	1	1922
	All	7	208440

Dutch			
	Alpino	3	13603
	LassySmall	0	7341
	All	3	20944

Table 2.3. Universal Dependencies results for SOV languages

Japanese		CE	Total
	GSD	2	8100
	Parallel Universal Dependencies	5	1000
	Balanced Corpus of Contemporary Written Japanese	19	57109
	All	26	66209

Korean		CE	total
	Kaist	3	27363
	GSD	18	6339
	Parallel Universal Dependencies	10	1000
	All	34	34702

Latin		CE	Total
	PROIEL	14	18411
	Index Thomisticus	9	26977
	Late Latin Charter Treebank	0	9023
	Perseus	4	2273
	UDante	3	1721
	All	30	58405

Persian			
	PerDT:	2	29107
	Seraji	0	5997
	All	2	35104

Table 2.3. Universal Dependencies results for SOV languages, continued

Turkish		CE	total
	BOUN	9	9761
	Framenet	0	2698
	GB	0	2880
	IMST	0	5635
	Kenet	0	18687
	Parallel Universal Dependencies	6	1000
	Penn	26	9557
	Tourism	0	19749
	All	41	76890

There is a noticeable correlation between syntax type and prevalence of center-embedding: two-level center embeddings, as defined in the search, are found to be much more common in SOV languages. This can be observed clearly in Figure 2.2, which displays the prevalence of center-embedding across the language corpora that were searched.

As evident in these statistics, there is a very clear difference between SVO (plus mixed) and verb-final languages, with verb-final languages (generally) having far more center-embedding than either of the other types. This striking difference is confirmed statistically by pairwise Fisher's exact tests (Table 2.4).

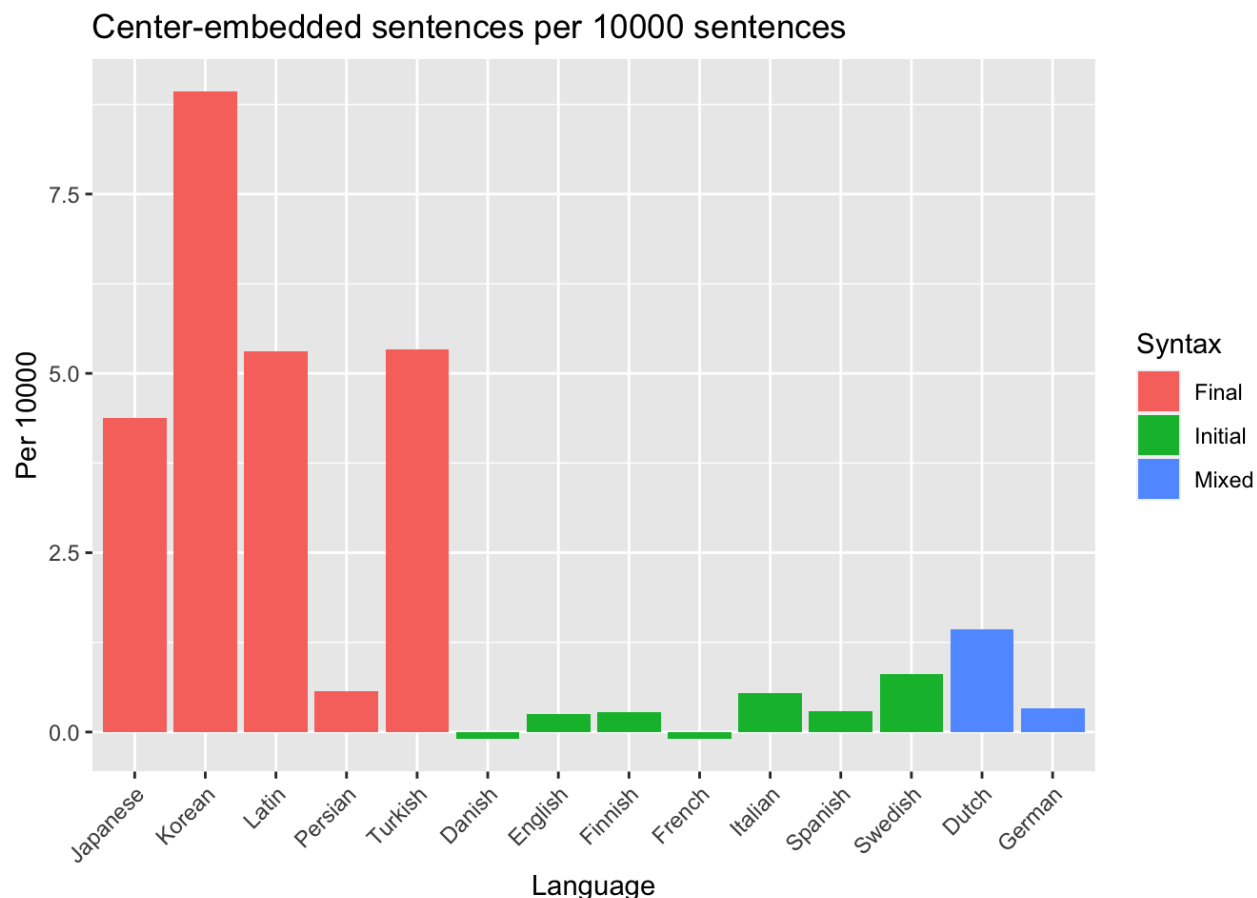


Figure 2.2: Two-level center-embedded sentences (per 10000) by language and syntax type

Table 2.4. Fisher's test statistics for center-embedding across syntax types, all comparisons:

Comparison	Fisher's p-value
SOV vs. SVO:	<. 0001 ***
SVO vs. mixed:	.86
SOV vs. mixed	<. 0001 ***
SOV vs. combined mixed and SVO:	<. 0001 ***

With regard to SVO European languages, the relative rarity of center-embedding in these corpora is consistent with the observations of Karlsson (2007), but the idea that center-embedding is universally disfavored across languages and syntactic types is not supported. In relation to the experimental results surveyed in Chapter 1, it was hypothesized that languages which allow or mandate verb-final order (e.g. Japanese, Korean, Latin) would

have a higher rate of center-embedding than languages which are strictly SVO (e.g. English, French). This hypothesis was generally confirmed.

The language with the highest rate of center-embedding (about 8 in 10000) is Korean. This result is what would be expected based on the experimental evidence present in Section 1.4.3. Not only is Korean an SOV language (resulting in center-embedding of complement clauses, by default), it has a case-marking system with phonological variation that may contribute to making center-embedding more processable. As discussed in Section 1.4.3.2.3, doubly center-embedded sentences with a transitive verb in C3 are acceptable in Korean while equivalent sentences are not in Japanese (which has generally similar SOV syntax). The supposition that Korean is more permissive of center-embedding than even other SOV languages is supported by this data.

While most head-final languages display a high rate of center-embedding, Persian does not; its rate of center-embedding is less than 1 in 10000, closer to that observed for SVO languages. The relative absence of center-embedding in Persian is likely due to a language-specific constraint mentioned in Chapter 1, Section 1: complement clauses for bridge verbs like “to know” are normally extraposed rather than being placed before the verb, so the typical pattern of multiple center-embedded complement clauses seen in languages like Korean is ruled out (Dryer 1980).

2.2.2.2. Center-embedding and inflection: English versus the Romance languages

Another prediction suggested by some experimental data (summarized in Chapter 1, Section 3) is that SVO languages with a richer inflectional system might permit more center-embedding than English, which has very little verb agreement inflection (Hoover 1992 on Spanish, Amy & Noiset 1978 on French). This hypothesis was not confirmed, as English and the surveyed Romance languages (French, Spanish, and Italian), along with the other SVO languages in the sample (Danish, Swedish, and Finnish) all had similarly low levels of

center-embedding: about 1 per ~30,000 sentences. Two languages, Danish and French, had none at all. Therefore, if inflectional differences or other factors truly make center-embedding more processable in some SVO languages than others, these factors are not apparent in this sample.

2.2.2.3. Written versus spoken corpora

A third prediction based on previous corpus research (Karlsson 2007, 2020; Laury & Ono 2010) is that multiple-center embedding would be very rare if not entirely nonexistent in spontaneous speech. The results of the present study are compatible with this assumption, though the available evidence is limited. Three of the corpora – one in English and two in French – contained samples of spoken language rather than sentences originally from a written source. None of these had any matches for center-embedding, which is consistent with the observations in Karlsson (2020). However, English and French are SVO languages with a generally low rate of multiple center-embedding (no matches for any corpora in French were found on this search), and no spoken corpora were available for languages with SOV order. Therefore, the question of spoken center-embedding in languages with SOV syntax is still open; Laury & Ono (2010) found that multiple center-embedding appears to be absent in spoken Japanese, but whether the same applies to other SOV languages is not clear. In addition, I have observed an instance of multiple center-embedding in spontaneous English conversation (from a non-linguist native speaker¹ without detailed knowledge of the topic):

12. [C1 Finding out that
 [C2 what
 [C3 you've got]
 can be treated]
 is a big help.]

(Note, again, the indexical pronoun subject of C3, a widely observed facilitating factor that will be addressed further in the following section 2.3.3.) Larger spoken corpora with appropriate

¹ She was, however, my mother. Perhaps something runs in the family.

tagging, for languages of all syntactic types, would be necessary to meaningfully compare writing and speech in this regard.

In conclusion, the hypothesis that head-final languages would permit more center-embedding has been supported, along with the idea that Korean in particular is highly permissive of center-embedding. All SVO languages surveyed have a very low rate of embedding, and the supposition that the Romance languages, with their richer inflection, might be more tolerant of center-embedding was not confirmed. Finally, multiple center-embedding was completely absent in the spoken corpora that were investigated.

In the following section, I will present a closer analysis of some of the sentences retrieved from the corpora, along with naturalistic English examples observed “in the wild,” to explore to what extent the known facilitating factors observed in experiments also manifest in naturalistic production.

2.3. Facilitating factors in some naturally occurring center-embedded sentences

In Section 1.2 I have discussed some observed English sentences with multiple center-embedded clauses in relation to the facilitating factors confirmed by experiment. Now I will address these sentences, along with some from the corpus search discussed in Section 2.2., in more qualitative and quantitative detail. In this section I will explore how some of the experimentally determined facilitating factors detailed in Chapter 1 manifest in a sample of naturalistic center-embedded sentences across several languages. These factors are C1 and C2 clause type (Section 2.3.1); type of subject in each clause (Section 2.3.2), with particular attention to English and Korean; and variation in case marking in Japanese and Korean (Section 2.3.3.). Finally, I will examine one example of an English sentence with three levels of center-embedding (Section 2.3.4.) and how it exemplifies the factors at hand despite its great complexity.

The set of sentences analyzed is different but overlapping with the set of sentences quantified in Section 2.3, which covers all results from the Universal Dependencies corpus search. Not all sentences found in the corpus search were available for analysis at the time of this writing (specifically, not all of the Turkish sentences have been analyzed by native speakers). The sentences found through the corpus search and analyzed in this section are in Appendix A. In addition, over 150 “found” English examples (Appendix B) have been included in the analysis for this section. The number of sentences analyzed in each language is shown in Table 2.5.

Table 2.5: Number of sentences analyzed qualitatively, per language and syntactic type

SVO: 165	Mixed: 10	SOV : 98
English (corpus): 1	Dutch: 3	Latin: 31
English (found): 158	German: 7	Japanese: 26
Finnish: 1		Korean: 31
Italian: 2		Persian: 2
Spanish: 1		Turkish: 8
Swedish: 1		

Sentences were manually tagged for the following parameters:

1. type of clause (adverbial, complement, relative subject/object/genitive/oblique), for C2 and C3.
2. type of clause subject (descriptive DP or NP, name, indexical pronoun, zero, etc.), for main clause and center-embedded clauses; these were ranked by accessibility based on Ariel (1994) and Gundel et al. (1993). The relationship between accessibility of subject and clause depth (C1, C2, et cetera) was analyzed with a linear mixed effects model including language as a random effect for all cross-linguistic data, and with a linear model for individual languages. In the model, subjects were coded for referential form

along an accessibility scale (with higher values corresponding to less accessible referents), clauses by depth (from 1 for C1 to 3 for C3).

3. In Japanese and Korean: case marking (topic, nominative, or zero subject) for subjects of main clause and center-embedded clauses.

In the following sections I discuss each of these factors in detail, with attention to which patterns are most commonly observed and how these correlate with experimental results on the processing of center-embedding (the facilitating factors discussed in Chapter 1). The observed frequencies of different factors are broadly consistent with the elements that have been experimentally observed to facilitate comprehensibility and acceptability of center-embedded sentences; i.e. those factors which make processing easier occur more frequently than the “hard” variations, though sentences with more difficult features are not entirely absent. Furthermore, these factors (e.g. pronoun subjects that are not introducing new referents) are even more prevalent in C3 than C2, reflecting the greater difficulty that manifests within the deeper embedded clause.

2.3.1. Type of embedded clauses

2.3.1.1. Overview

Every sentence in the analysis set was tagged for the type of clause appearing in C2 and C3: adverbial, complement, or relative (which in turn were classified by type of relativized DP/NP, following the accessibility hierarchy of Keenan & Comrie). Results for clause type with depth are shown in Figure 2.3.

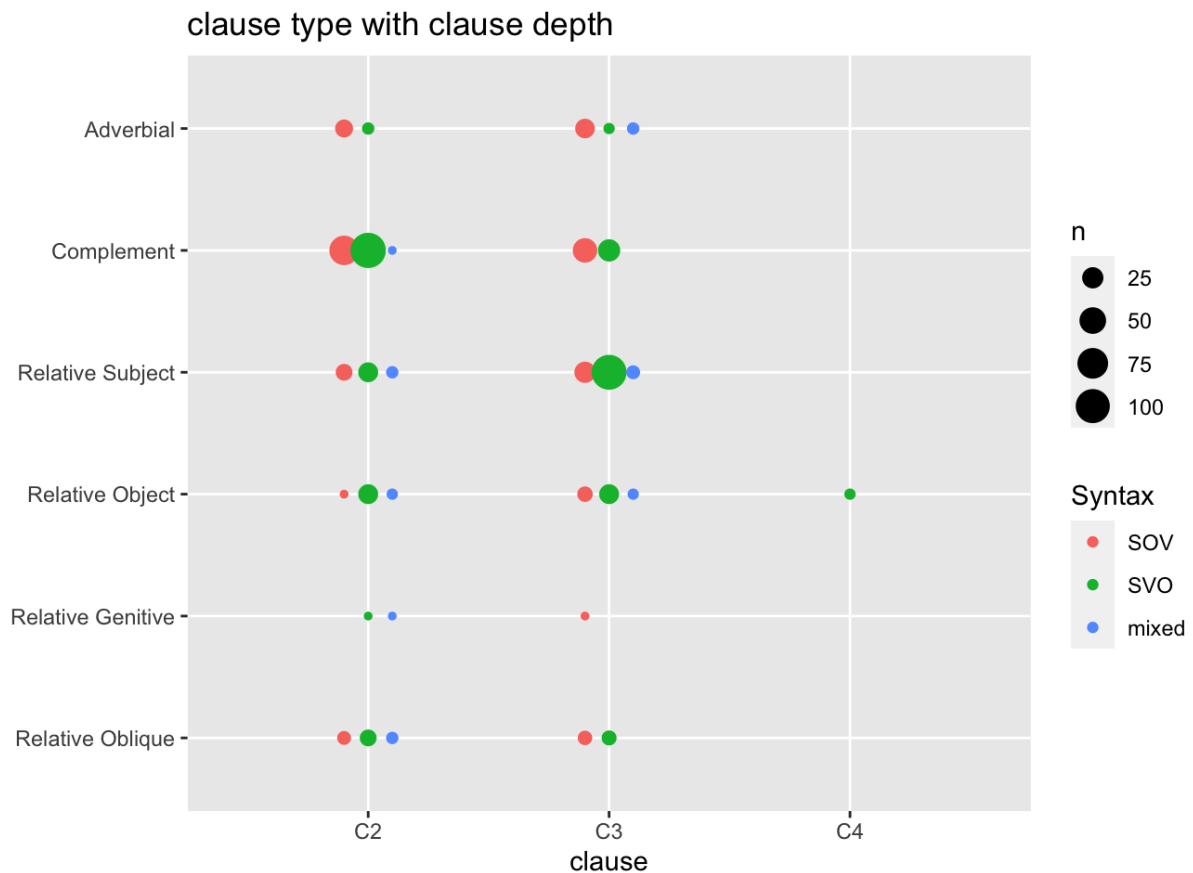


Figure 2.3: Type of embedded clause with clause depth for all analyzed sentences

As can be observed, complement clauses and subject relative clauses predominate across all syntax types. A common configuration (90 of all 273 sentences, about one third of the data) for a sentence with two center-embedded clauses is a complement clause C2 and a subject relative clause C3. This prevalence holds for all word order types, though exceptions can be found. As explored in Section 1.2.1.1, this clausal configuration is exactly that revealed by experimentation and observation to be the easiest to comprehend.

Adverbial clauses are the next most common type of center-embedded clause after complement clauses and subject relative clauses: 17 C2s and 24 C3s. They are less common than complement and subject relative clauses, but more so than the rarer relative clause types

discussed below. (13) includes an example of an adverb clause C3 (“when she found us”) within a subject relative C2:

13.

[C1 The tamed-fox
she called "Baby,"
[C2 who
[C3 when she found us]
followed her like a child
and was doted on like so,]
was more than proof enough that she understood the same principles.] (Bajda 2022)

The processability of adverbial clauses compared to other types of center-embedded clauses is not well-studied. In the following subsections, I will focus on complement clauses and relative clauses, with attention to the subject/object relative distinction (and other types of relative clauses where they occur).

2.3.1.2: English and other SVO languages

In the analyzed English sentences and those (very few) from other SVO languages, observed frequencies of relative clause types, and the combination of complement and relative clauses, closely parallels experimental results about which types and configurations are the most processable (see Section 1.2.1.1 for an overview). Specifically, subject relative clauses are far more common than other relative clause types, object relative clauses the next most common (23 C2s, 30 C3s), and types lower down Keenan & Comrie’s accessibility hierarchy (namely object, oblique and genitive relative clauses) are rare.

As discussed in Section 1.2.1.1, doubly center-embedded sentences featuring a subject relative clause C3 within a complement clause C2 are relatively easy to process. Complement clauses are easier to process than relative clauses because they lack a filler-gap dependency, reducing total dependency length (Gibson & Thomas 1998), and subject relative clauses are overall easier to process than other relative clause types, particularly object relative clauses, because of their lower (structural) distance between filler and gap (O’Grady 2011). In addition,

Gibson & Thomas (1998) showed that center-embedded sentences with a complement clause C2 and a subject relative clause C3 were easier to process than those with the reverse configuration. We would therefore expect the “easy” combination of complement and relative clauses to be common in the corpus data, and this is just what we see. This configuration, seen in (14), is by far the most common in the English data, accounting for nearly half the observed English sentences (72 out of 159).

14. Complement C2 and subject relative C3:

[C1 The reveal at the end
 [C2 that a wise character
 [C3 who teaches the lead about Candyman]
 was somehow doing Candyman’s bidding
 or otherwise preparing the way for Candyman]
 neither makes much sense to me nor adds anything to the story.](De Boer 2022a).

The opposite configuration, with a complement clause C3 inside a relative clause C2, was rare (8 examples across all types of relative clause C2). Interestingly, one of these sentences (15) features a configuration observed by Gibson and Thomas (1998) to be particularly difficult, a complement C3 within an object relative C2 (“anger [that the fact... can still generate]”):

15. Object relative C2 and complement C3:

[C1 the strange, seemingly genuine *anger*
 [C2 that the mere fact
 [C3 *Avatar* is the highest-grossing movie of all time]
 can still generate among a certain subset of extremely online nerds]
 is kind of funny.]
https://old.reddit.com/r/HobbyDrama/comments/z067ox/hobby_scuffles_week_of_november_21_2022/ixr6jfi/

The observation of a sentence like this in naturalistic discourse suggests that even seemingly difficult center-embeddings may be tolerated, although they are not nearly as common as more easily processable configurations.

Of all relative clause types, subject relative clauses were the most common in English: 20 in C2, 101 in C3. Object relative clauses were next most common but much less frequent than subject relatives in C3: 18 C2s, 20 C3s, and one C4. (16) is one of 11 examples containing a subject relative C3 inside an object relative C2:

16. Object C2 and subject C3:
 [C1 But whatever
 [C2 the AI
 [C3 that kills us]
 really does]
 will probably be weirder than that.] (Alexander 2022)

Genitives and oblique relative clauses are rarer still: the only center-embedded genitive relative clause found in English is C2 in (17):

17. Genitive C2 and subject C3:
 [C1 A Marine officer
 [C2 whose viral videos
 [C3 criticizing senior officials
 for how they withdrew from Afghanistan]
 created a political uproar]
 will plead guilty to several charges] (Lamothe 2021)

Finally, oblique relative clauses (e.g. prepositional) also appeared rarely, constituting 11 C2s and 7 C3s in the English data; (18) features the oblique C3 “in which...”.

18. Complement C2 and oblique C3:
 [C1 Number four, using the language of social justice and progressivism
 [C2 to argue
 that the market
 [C3 in which you are selling products]
 should be less competitive]
 is, well, gross.]
 <https://www.metafilter.com/194250/30-games-a-day#8204569>

Overall, the frequency of subject relative clauses compared to other types is consistent with the common experimental observation (see Section 1.2.1.2 for a summary) that subject relative clauses are easier to process than object relatives, and this difficulty particularly manifests in cases of multiple center-embedding. The acceptability of relative clauses other than subject and object in center-embedding is not well studied (see Section 1.2.1.2 on types of relative clauses in English). However, the present analysis of found English examples suggests that types of relative clause lower down the Keenan/Comrie accessibility hierarchy (i.e. genitives and obliques) may be as unacceptable or worse than object relatives. Alternatively, the

comparative rarity of genitive and oblique relative clauses in these center-embedded examples may simply reflect overall lower frequency (Roland et al. 2007).

The difficulty posed by object relative clauses also manifests in how uncommonly they occur as both C2 and C3. Sentences with two center-embedded object relative clauses, a configuration which Karlsson (2007) found to be nonexistent in his corpora, occurred only twice, one of which is shown in (19):

19. Doubly center-embedded object RCs:

While it's always interesting to realise that

[C1 something

[C2 which every child

[C3 you've met]

has taken for granted]

is seen as strange in other parts of the world...]

<https://www.metafilter.com/193594/Are-you-a-good-person#8181525>

However, it is known that doubly-embedded object relative clauses can be processable (see discussion in Section 1.2.2.1.1.2, and Bever 1970) so their very rare appearance here could be a function of small sample size. Note that the C2 and C3 subjects in the above are a quantified phrase ("every child") and an indexical pronoun ("you"), so some expected facilitating factors are present. In the following subsection (2.3.1.3.) I will say more about the presence of these factors, specifically with regard to subjects, in the analyzed corpus and found examples.

The very few non-English SVO language examples found in the corpus results show the same general patterns as English, as seen in these examples from Spanish (20) and Italian (21), which feature a complement clause C2 and a subject relative C3:

20. Spanish complement clause and subject relative clause:

[C1 La circunstancia

[C1 DEF.F.SG fact

[C2 de que el 80% de los turista-s

[C2 of that DEF.M.SG 80% of DEF.M.PL tourist-PL

[C3 que lleg-uen a Catalunya]

[C3 who arrive-3PL.PRES to Catalonia]

lo hag-an por carretera]

INDEF.SG do-3PL.PRES by roadway]

restar-á transcendencia a los problem-as aeroportuario-s,

reduce-3SG.FUT importance to DEF.M.PL problem-PL airport-ADJ-PL

según el conseller de Indústria, Antoni Subirà.]

according.to DEF.M.SG minister of industry, A. S.]

“The fact that 80% of tourists who arrive in Catalonia do so by road will reduce the importance of airport problems, according to the Minister of Industry, Antoni Subirà.”

21. Italian complement clause and subject relative:

[C1 il perché

[C1 DEF reason

[C2 la linea ferroviaria

[C2 DEF line railway

[C3 che port-ava a Flensburg]

[C3 that go-3sg.IPFV to F.]

non fu mai utilizz-ata correttamente per l'evacuazione]

NEG was ever use-PTCP correctly for DEF.evacuation]

riman-e tuttora motivo di dibattito tra gli storici.]

remain-3sg.PRES still matter of debate among DEF.PL historians]

“The reason the railway line that goes to Flensburg was never properly used for evacuation remains a matter of debate among historians to this day.”

To recapitulate, naturalistic observations of clause types in center-embedded sentences in SVO languages generally align quite well with what experimental and theoretical analyses would predict: i.e. the most common configuration is a complement C2 with a subject relative C3, subject relatives overall are the most common relative clause type, and other types of relative clauses are much less frequent.

2.3.1.3: SOV and mixed-headedness languages

In the analyzed corpus search results from SOV and mixed-headedness languages, similar patterns to English and other SVO languages generally hold with regard to preferred configuration of clause types. 16 of all 108 sentences show the familiar configuration of a complement clause C1 and a subject relative clause C2, as seen in German (22):

22. German complement clause and subject relative clause:

[C1 Intel-s Argument ,

[C1 Intel-GEN claim

[C2 der 2 Kilobyte große Daten-block ,

[C2 that 2 kilobyte large data-block

[C2 der aus dem BIOS in den Chip transferier-t wird ,

[C2 that from DEF.DAT BIOS to DEF.ACC chip transfer-PTCP become.PRES.3sg

sei doch verschlüsselt und nirgends dokumentiert,]

be.SBJV actually encrypted and nowhere documented]

nutz-t da wenig .]

use-PRES.3sg so little]

"The claim of Intel, that the 2-kilobyte data block that is transferred from BIOS to the chip is alleged to be encrypted and nowhere documented, doesn't help much."

However, double complement clauses occur in SOV languages as well and constitute the most common combination of clause types in the data (29 out of 98 analyzed SOV sentences). Examples are shown from Korean in (23), Japanese in (24), and Turkish in (25):

23. Korean complement/complement:

[C1 lentupulaytu taypyenin-un

[C1 L.B. spokesperson-TOP

[C2 choykun suweyteyn swusatay-ka

[C2 recently Sweden investigators-NOM

[C3 ku-ka thekhi hangkonga-eyse ilha-ko iss-ta-nun]

[C3 he-NOM Turkey airline-LOC work-COMP be-PST-NMNL]

ceypo-nun pat-ass-tako]

information-TOP receive-PAST-COMP]

malhay-ss-ta.]

say-PST-DECL

"Spokesperson L.B. said that the Swedish investigating team recently received information that he is working at the Turkish airline."

24. Japanese complement/complement:

[C1 doutai-ha

[C1 the team-TOP

[C2 XXXyougishara-ga

[C2 suspect.XXX.and.coworkers-NOM

[C3 kaigai-de hakkousareta

[C3 overseas issued

kaado-no baai-ha chekku-ga amai koto-wo]

card-GEN case-TOP check-NOM lax that-ACC]

akuyoushita-to]

exploit-PST]

miteiru]

imagine]

"The team believes that suspect X and their coworkers took advantage of the fact that credit cards issued overseas are subject to lax security checks."

25. Turkish complement/complement:

[C1 Diğerleri ,

[C1 others

[C2 Bush yönetiminin

[C2 Bush administration.gen

[C3 her iki taraftaki söylemin de kontrolden çıktığını]

[C3 every two side.DAT.ADJ statement.GEN too control.ABL get.out.of.FNom.3sg.ACC

düşünebileceğini]

think.ABIL.FNomFut.3sg.ACC

söyledi .]

say.PAST

“Others said that the Bush administration might think statements from both sides got out of control.”

In summary, the common complement C2/subject relative C3 pattern of SVO languages is present in SOV and mixed-headedness languages but not as prevalent. Instead, the most common configuration in the SOV language data is two center-embedded complement clauses. As discussed previously in Section 1.1., SOV word order is conducive to complement clauses, whether of nouns or verbs, being center-embedded. These expectations are supported by the present data.

2.3.2. Type of subjects in main and embedded clauses

In analyzing the types of clausal subjects that were present, a scale of specificity based on the analyses of Ariel (2014) and Gundel et al. (1993) was employed (see section 1.2.2.1.1.). Definite descriptions or other NPs/DPs introducing new referents are the most specific; names less so; bare plurals, quantifiers/indefinite pronouns, and third-person pronouns less specific than names; and indexical pronouns and zero subjects least specific of all. Examples of each category are listed in (26):

26.

Descriptive NP: *the N, a(n) N* (when introducing new referent in context)

Name: *John, Mary, Joe Biden ...*

Bare plural: *men, things, animals ...*

quantifier/indefinite: *everyone, somebody, some/any/all N*

Pronoun (3rd person): *he, she, they*

Indexical: *I, you, we*

Zero: gap as in *the student [_ using the computer]*

As the graph of all included language data (Figure 2.4) shows, there is a general trend for less specific subjects to occur in embedded clauses, although descriptive subjects can appear in all clauses.

Since all of these sentences occurred as part of naturalistic discourse – e.g. journalism, fiction, or online discussion – the noun phrases featured in them likely had referents already introduced in context, which would reduce the usual difficulty associated with introducing a new referent. Therefore, the facilitating factors present in real-world center-embedding may not be as prevalent as might be expected from experimental results, but generally speaking a trend is observable: in more deeply embedded clauses, less specific and more accessible subjects are favored. For example, zero subjects may occur, and referential subjects are less common.

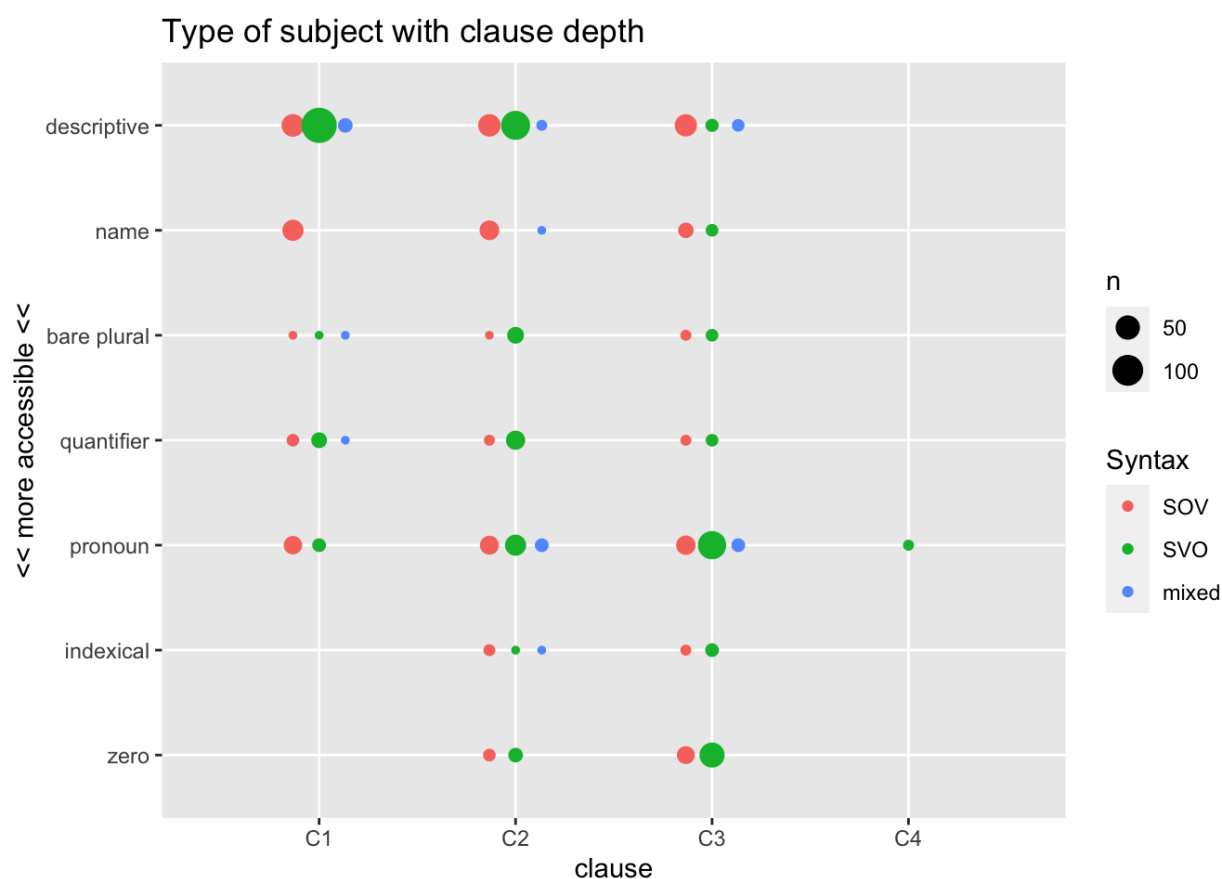


Figure 2.4: Type of subject with clause depth, all analyzed sentences.

A linear mixed effects analysis was performed with language as a random effect, coding the categories in (26) from least accessible (descriptive DP, 6) to most accessible (zero subject, 0). This analysis shows that there is a significant trend for more accessible subjects in more deeply embedded clauses ($B = -1.46$, $SE = 0.079$, $p < .0001$).

I will now look more closely at two languages for which I have many examples, and for which there exists prior experimental research on the role of subject types: English and Korean. These languages are very different typologically: English is SVO and has little inflection, whereas Korean is SOV and has a case-marking system. The experimental results for these languages suggest different preferences and factors at work, and this discrepancy is apparently confirmed by the English “found examples” and an examination of Korean corpus results. Specifically, Korean is more tolerant than English of pronoun or proper name subjects in main clauses, and of descriptive subjects in embedded clauses.

2.3.2.1. English

I have previously discussed some relevant English examples in section 1.2.2.1.3, and this quantitative observation shows that the general trend for low-accessibility subjects (e.g. definite descriptions) in main clauses, and more accessible subjects such as pronouns or quantifiers in embedded clauses, holds across this sample of 159 sentences. Figure 2.5 shows data on subject referential form and clause depth for English alone.

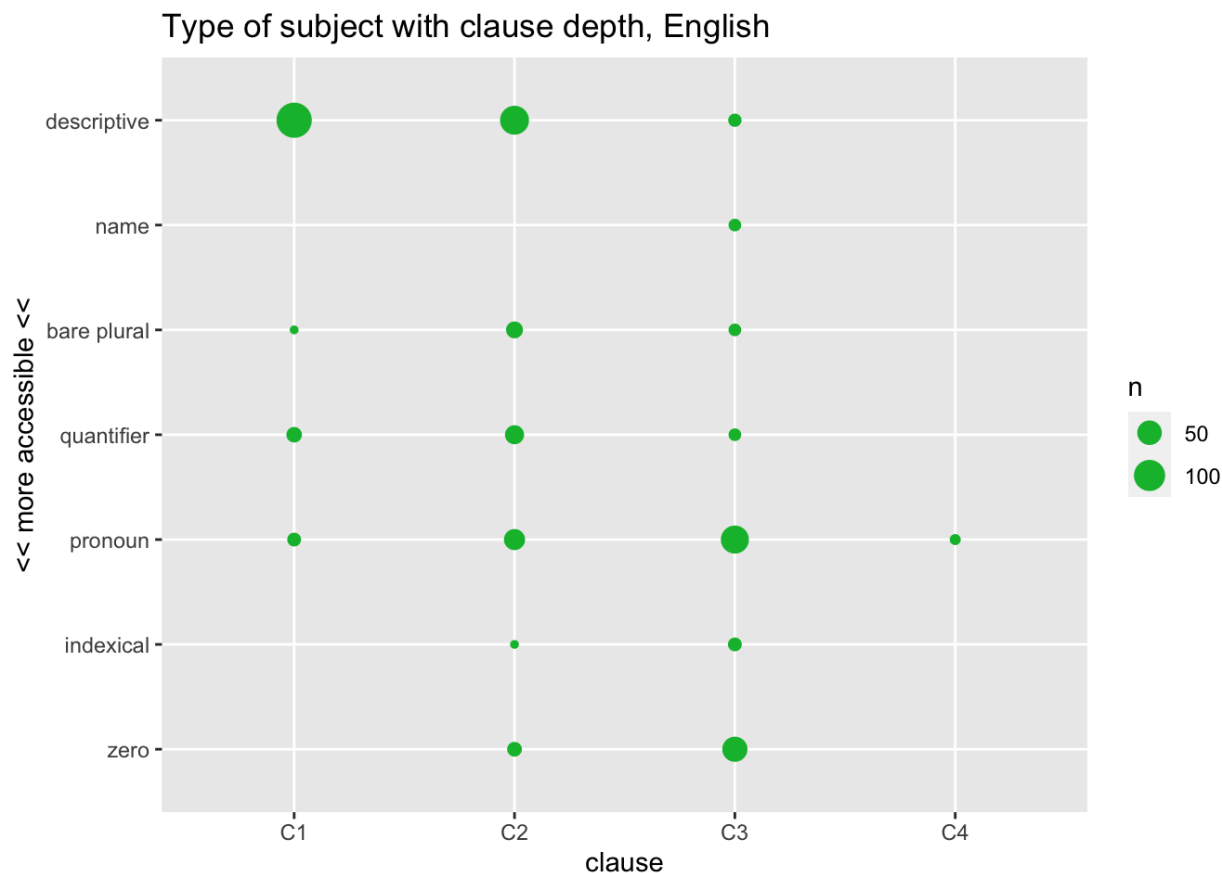


Figure 2.5: type of subject with clause depth, English.

Descriptive / low-accessibility subjects appear in 139 of 159 main clauses, 81 C2s, and only 5 C3s, although in the (very common) case where C1 is a complement clause, there are generally abstract subjects like *the fact*, *the idea*, etc, or gerunds like *saying* or *believing*. Quantifiers and bare plurals show a tendency to appear as C2 subjects (22 quantifiers, 14 bare plurals) more than either C1 or C3 subjects. This observation is strikingly consistent with the results of Warren and Gibson (2002).

Furthermore, this qualitatively observed tendency for “deeper” subjects to be lower on the referentiality scale is also confirmed to be significant by a linear model comparing type of subject to clause depth ($B = -2$, $SE = 0.09$, $p < .0001$). A gradation from more to less referential subjects with embedding depth can be observed in these examples (27-8):

27.
 [C1 The fact that
 [C2 anything
 [C3 resembling a manuscript]
 was finally assembled]
 is nothing short of miraculous.] (Kelly 2005: 323)

Here, the subject of C1 is definite (albeit the abstract “fact”), C2’s subject is an indefinite pronoun, and C3 is nonfinite with a null subject.

28.
 [C1 the things
 [C2 people
 [C3 who profess utter devotion to their welfare]
 do to them]
 appall me.]

In (28), C1 is again a definite subject, although one with a non-specific referent; C2 is a bare plural, and is also semantically vague in the sense used in Section 1.2; i.e. “people” carries little semantic specificity. Finally, C3 is a subject relative clause and therefore not introducing a new referent as its subject.

Overall these results from the found English center-embedded sentences are what would be expected from experimental findings such as Warren & Gibson (2002). In particular, definite descriptions appear commonly as the subjects of main clauses, and within embedded clauses, more accessible subjects appear, including quantifiers and indexical pronouns.

2.4.2.2. Korean

As discussed in Section 1.4.3.2.2.2, Korean center-embedded sentences are easier to process when main and embedded clauses include different referential forms. However, Korean shows a different pattern from English with regard to the most processable combinations of subjects in center-embedded sentences: sentences with a pronoun in the main clause C1 and a descriptive NP in an embedded clause are easier to process than the reverse configuration. Since Korean is pro-drop, pronoun subjects may introduce new discourse referents, as do

definite descriptions in non-pro-drop languages like English. The prevalence of this pattern in naturalistic discourse is confirmed by the corpus data.

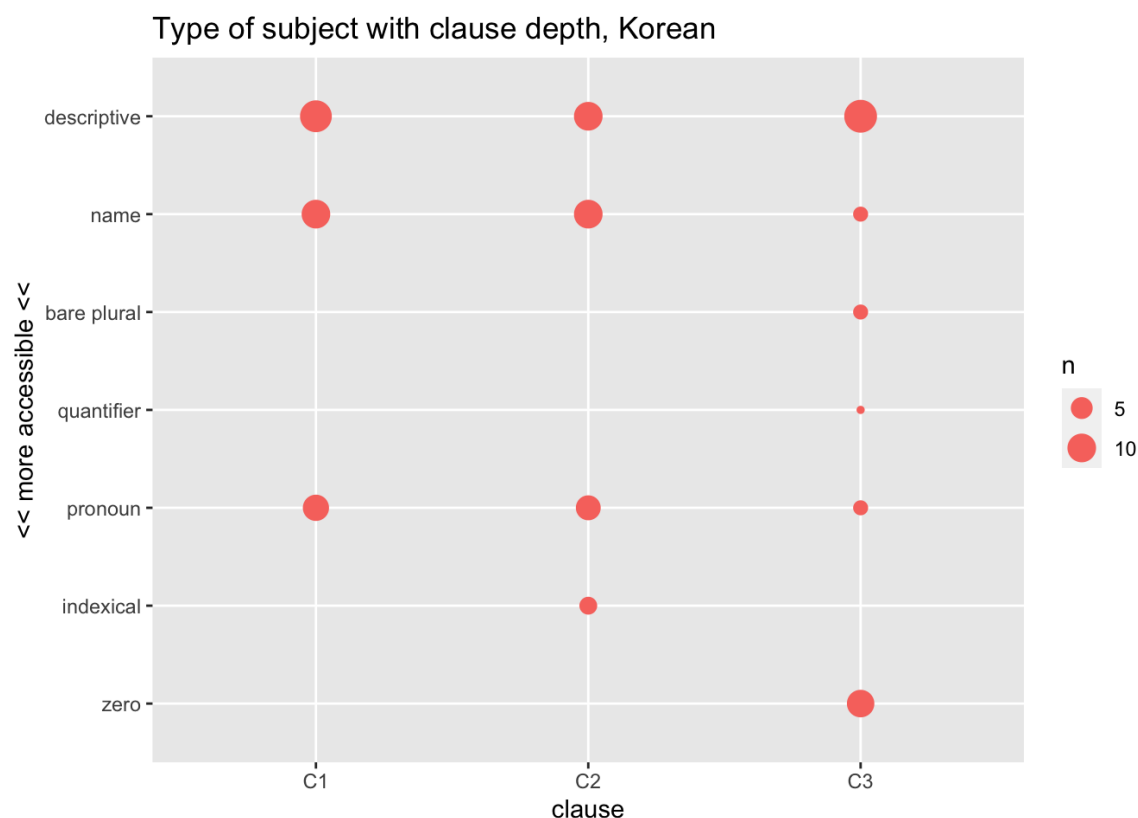


Figure 2.6: type of subject with clause depth, Korean.

Figure 2.6 shows data on subject referential form and clause depth for Korean alone. Unlike in English, descriptive / low accessibility noun phrase subjects are more permissible in Korean center-embedded clauses (appearing in 13 C1's, 11 C2s, and 15 C3s), while proper names can occur at all clause levels, but appear to be less acceptable in C3 (10 each in C1 and C2, 2 in C3) and pronouns are accepted as subjects of the main clause almost as often as less accessible subjects. Specifically, of the 31 sampled Korean sentences, 8 have pronoun main clause subjects, 10 have proper names, and 13 have lower-accessibility NP subjects -- unlike English where nearly all main clause subjects were descriptive in nature. Pronoun subjects are

also less prevalent in Korean embedded clauses than in their English equivalents: 6 instances occurred in C2 and only 2 in C3, whereas higher-accessibility subjects constitute the bulk of the English C3 subjects. Therefore, the gradation seen in English – low-accessibility descriptives as main clause subjects, quantifiers in C2, and pronouns or zero subjects in C3 – does not hold so clearly for Korean. This is reflected by the results of a linear model comparing accessibility of subject (coded from 0 for zero subjects to 6 for descriptive subjects) to depth of clause (coded from 1 for the main clause to 3 for C3) across the Korean sentences: i.e., the tendency for embedded clauses to have subjects higher in accessibility is present but weaker than in English, and therefore not significant ($B = -0.5$, $SE = 0.27$, $p = 0.06$).

Just as the observed frequencies of different subject types for English center-embedded clauses match what would be expected from the experimental results described in section 1.2.2.1.1, the results for Korean parallel the experimental evidence on referential form in this language (Lee & Stromswold 2007, summarized in Section 1.4.3.2.2.2). This pattern can be observed in these Korean examples, (29) and (30):

- 29.
- | | | | |
|-----|---|-----------------------------|--------------------------------|
| [C1 | ikes-i | palo | |
| [C1 | this-NOM | in.itself | |
| | [C2 | wuli-tul-i | ettehkey |
| | [C2 | we-PL-NOM | how |
| | | [C3 | sayngmyeng-i mwues-i-nci-lul] |
| | | [C3 | life-NOM what-COP-Q-ACC] |
| | cikkwancekulo | al-ko.iss-nunci-ey.tayhan] | |
| | intuitively | know-PRS-Q-for] | |
| | selmyeng-i-ta.] | | |
| | explanation] | | |
| | 'This is the explanation for how we intuitively know what life is.' | | |

The subject of C1 is a demonstrative pronoun, presumably referring back to an earlier concept introduced in the discourse. C2's subject is an indexical pronoun, whereas the subject of C3 is a noun, albeit a vague (in the sense I have used) and abstract one.

30.
 [C1 ku-nun
 [C1 he-top
 [C2 “cwungkwuk cengpwu-nun
 [C2 China government-top
 hongkhong-uy ippep mapi-ka cisok-toy-ci.anh-tolok]
 Hongkong-gen legislation paralysis-nom continue-pass-neg-comp
 [C3 haki.wihayse cwungkwuk-uy kayip-i philyoha-tako]
 [C3 in.order.to China-gen intervention-nom be.necessary-comp]
 sayngkakha-n-ta”-lako]
 think-prs-dec-comp
 malha-yss-ta].
 say-pst-dec
 ‘He said, “The Chinese government thinks that, in order for the paralysis of Hongkong’s
 legislation to not be continued, China’s intervention is necessary.”’

The subject of C1 in (30) is a third-person pronoun, again likely referring back to a previous discourse referent. Both complement clauses, C2 and C3, have referential NPs as subjects: the government of China, and China’s intervention.

Just as the patterns of clause subjects observed in the English found examples broadly parallel experimental results such as Warren & Gibson (2002), the results for Korean parallel experimental work in this language (particularly Lee & Stromswold 2007). In English, more accessible / less informative subjects, such as quantifiers and pronouns (especially indexicals) appear more commonly in embedded clauses, whereas descriptive subjects tend to appear in main clauses. Korean shows a weaker version of this same pattern: it is more tolerant of pronouns and other highly accessible subjects as main clause subjects, and less-accessible subjects, including names and descriptive NPs, in embedded clauses. Each language shows a distinct pattern as to which subjects make embedded clauses more processable, and this pattern holds across experimental research and corpus observations.

2.3.3. Japanese and Korean case marker variation

Case marking has been analyzed as a facilitating factor for processing of multiple center-embedding in the best-studied SOV languages, Japanese and Korean (see Sections 1.4.2.2.4.1 for Japanese and 1.4.3.2.2.1 for Korean), and it has been shown that variation in case markers makes processing and comprehension easier. For example, in Japanese, center-embedded sentences with three consecutive subjects bearing the nominative case are more difficult to process than those in which the case markers are varied, such as the main clause subject being topicalized or a relative clause subject being marked as genitive rather than nominative. This variation removes one source of similarity-based interference. Therefore, I examined the patterns of case marking that occur in the analyzed corpus examples (26 in Japanese, 31 Korean). The resultant observations are in line with the experimental results summarized in Section 1.4: for center-embedded sentences, different case marking on the subjects is preferred over identical case marking on all three.

In these languages, the observed center-embedded sentences typically feature some case-marker variation, which would be expected given the previously summarized experimental work on the role of case as a facilitating factor to avoid similarity-based interference. Specifically, center-embedded sentences where all three clause subjects are nominative-marked are harder to process than those where at least one case marker is different from the others; therefore we would expect naturalistic center-embedded sentences to show case marker variation as well.

A preference for case marker variation is indeed observed in the naturalistic data for both languages. For example, the subject of the main clause C1 may be topicalized while those of the embedded clauses are nominative, or both C1 and C2 subjects may be topicalized while C3 has a nominative subject. This combination of topic markers and nominative markers prevents the similarity-based interference which could occur if all case markers were identical.

Table 2.6 presents a summary of the case marking data for Japanese, and Table 2.7 for Korean. Examples of sentences with a combination of topic and nominative markers on the clause subjects, are shown from Japanese in (30) and Korean in (31). Rarely are the case markers all identical; notably, the results for Japanese contained no examples of center-embedded sentences with nominative subjects in all three clauses. These results from naturalistic data thus fit well with experimental evidence showing that both Japanese and Korean center-embedded sentences with identical case marking on all three subjects are hard to process (e.g. Lewis & Nakayama 2001, Suh 2000).

Table 2.6: Case marking of clause subjects, Japanese

Cases in C1/C2/C3	#sentences
Topic/topic/topic	2
Topic/topic/nominative	9
Topic/topic/zero	3
Topic/nominative/topic	4
Topic/nominative/nominative	8
Total	26

(31) represents one of the most common configurations in Japanese (9 of 26 sentences): the main clause and C2 both have topicalized subjects, while that of C3 is nominative.

31. Topic/topic/nominative, Japanese:

[C1 Kare-wa BBC-no Andrew Marr-no bangumi-de,
[C1 he-TOP BBC-GEN Andrew Marr-GEN show-at
[C2 "sousenkyo-wa, sottyō kuni itte,
[C2 general.election-TOP honestly say
[C3 seifu-ga mottomo yari-taku-nai]
[C3 government-NOM most do-want-NEG
koto-desu."]
thing-COP]

to karat-ta.]

C remark-PAST]

"In the Andrew Marr Show on BBC, he remarked that 'honestly speaking, the general election is the last thing that the government wants to do'." "

The observed patterns of case marking in Korean are more diverse than those in Japanese, but show the same overall trend: the majority of sentences show variation between the case markers of clause subjects.

Table 2.7: Case marking of clause subjects, Korean

Cases in C1/C2/C3	#sentences
topic/topic/topic	1
topic/topic/nominative	8
topic/topic/zero	4
topic/nominative/topic	2
topic/nominative/nominative	11
topic/nominative/zero	1
nominative/nominative/topic	1
nominative/nominative/nominative	2
nominative/nominative/zero	1
Total	31

As in the Japanese data, there is a tendency in Korean for some case marker variation in center-embedded sentences, e.g. the C1 subject may be topicalized while the other clauses have nominative subjects, or C1 and C2 subjects may be both topicalized while C3 has a nominative subject. By comparison, sentences with three nominative subjects are uncommon; only two were observed out of 31 sentences. (Zero subjects can also occur in C3.) The most common configuration in Korean (11 sentences of the 31) has a topicalized C1 subject and nominative subjects in embedded clauses, as illustrated in (32):

32. Topic/nominative/nominative, Korean:

[C1 lentupulaytu taypyenin-un

[C1 L.B. (NAME) spokesperson-TOP

[C2 choykun suweyteyn swusatay-ka

[C2 recently Sweden investigators-NOM

[C3 ku-ka thekhi hangkongs-eyse ilha-ko iss-ta-nun

[C3 he-NOM Turkey airline-LOC work-COMP be-PST-NMNL]

ceypo-nun pat-ass-tako]

information-TOP receive-PST-COMP]

malhay-ss-ta.]

say-PST-DECL

"Spokesperson L.B. said that the Swedish investigating team recently received information that he is working at the Turkish airline."

These corpus observations are in line with the experimental results summarized in Section 1.4:

for center-embedded sentences, different case marking on some of the subjects is preferred over identical case marking for all three consecutive subjects.

2.3.4. The limits of center-embedding: going three levels deep

A common assumption in the literature on multiple center-embedding is that sentences with three levels of clausal center-embedding are difficult if not impossible to process, at least in English. As discussed in Section 1.2.2.1.1.2, Bever (1974) argued that such sentences can be made at least marginally acceptable with variation in the subject noun phrases, and use of high-accessibility subjects in the deepest embedded clauses. However, actual examples with this level of complexity are very rare in naturalistic discourse, and likely confined to writing (see Section 2 of this chapter, and Karlsson 2007). No such examples were found through the corpus search, but I have observed one in reading – (33) occurred in a 2021 post on the advice blog *Ask A Manager*:

33.
[C1 Suggesting
[C2 that someone
[C3 who needs
the paycheck
[C4 they earned]
to be delivered to them on time]
“didn’t prioritize her bills
or save smartly”]
is wildly out of touch ...](Green 2021)

This sentence is Karlsson’s *rara avis*, particularly unexpected in a language like English where center-embedding is more disfavored, and nicely exemplifies the previously discussed facilitating factors of reference form and clause type. The indefinite “someone” appears as the subject of the complement clause C2; C3 (“who needs... on time”) is internally very complex but is a subject relative clause, a factor well known to ease processing, as no further referent needs to be introduced into the discourse (“who” referring back to “someone”). Furthermore “needs” is a stative verb, possibly another facilitating factor. The deeply embedded C4 is an object relative clause (“they earned”), but its subject is a pronoun whose referent is clear (the same referent as “someone,” and in the broader context, referring to an employee who complained about not getting a paycheck on time). This sentence is very complex, with right-branching as well as several center-embeddings, but the individual clauses are equipped with factors that decrease memory load, primarily the high-accessibility co-referential subjects.

Difficult as it may be in isolation, this sentence occurred in real discourse, and in addition the subjects of several of its clauses (*someone, who, they*) refer to the same referent, whose identity would have been fixed earlier in the context (an actual employee complaining). Most research on center-embedding has featured context-less sentences in experimental settings, so the role of context in facilitating difficult sentences has not been well-explored. The existence of such a complex sentence in natural discourse suggests that previous estimates of the

prevalence of naturalistic center-embedding, even in SVO languages like English, may be too low.

2.5. General discussion: center-embedding in the wild

Center-embedding, here defined as multiple embedded subject-verb dependencies, is generally rare, but far more common in SOV languages than SVO and mixed-headedness languages, as demonstrated by the corpus search results. Even in the most embedding-rich SOV language (Korean), the corpus results do not show more than about 1 in 1400 sentences with this pattern. Other SOV languages (Japanese, Latin, Turkish) have a rate of about 1 in 2000 sentences with multiple center-embedding. On the other hand, SVO languages showed rates of less than 1 in 10000.

As described in Chapter 1, Section 1, SOV languages with word order that forces center-embedding by default may avoid center-embedding using scrambling or extraposition. While scrambling and extraposition were not specifically searched for in this survey, the striking difference between rates of center-embedding in SOV and SVO languages suggests that center-embedding is not so strongly disfavored in the former, except likely in the case of Persian, which is SOV but has a rate of center-embedding more comparable to that of SVO languages. As mentioned earlier (Section 2.3.2), this difference between Persian and the other SOV languages may be a consequence of obligatory extraposition. How specific differences between languages with similar syntax may contribute to the frequency or rarity of center-embedding in individual languages is a useful topic for further research.

Throughout Chapter 1 I have evaluated real-life examples of center-embedded sentences, and found some recurring patterns that accord with the factors found in experiments and intuitive judgements to make center-embedding easier, including combinations of clause types (particularly complement C2s and subject relative C3 being the easiest pattern to process), types of subjects in embedded clauses, and case marker variation in Japanese and

korean specifically. I have quantitatively confirmed the prevalence of the same factors in corpus search results along with a more thorough examination of observed English examples: clause types, subjects of main and embedded clauses, and case marking variation in Japanese and Korean. For example, the subject noun phrases of embedded clauses C2 and C3 tend to be high accessibility (e.g. a pronoun with a discourse referent) or are sometimes dropped entirely, as in a participle with a null subject, or a subject relative clause. The particularly difficult construction of two center-embedded object relative clauses is found to be comparatively rare, whereas subject relative clauses and complement clauses are more tolerated, specifically the easily processable C2-complement C3-subject relative configuration (see Section 1.2.1.2 for details). However, to fully explore these factors, more tagged corpus data on an even wider range of languages would be necessary. Finally, as described in Section 2.3.5, casual observation of English naturalistic center-embedding reveals that acceptable examples of three-level embedding do occur, and also confirms the role of experimentally observed facilitating factors, namely combinations of clause types and subjects. Specifically, the subjects of the multiple embedded clauses all refer back to the same contextual established referent, rather than introducing new referents in mid-sentence.

Overall, these results demonstrate two important findings. First, center-embedding is not uniformly disfavored across all languages, but varies with syntactic type. Second, even in a language with a low incidence of multiple center-embedding, namely English, genuine examples are found – and these examples generally conform to the factors shown by experimentation to facilitate the processing and comprehension of center-embedded sentences. Even sentences with three levels of center-embedding can occasionally be observed, and nicely exemplify these facilitating factors. Together, these findings reveal that the difficulty of center-embedding is shaped by both universal factors of working memory and language-particular features, and that center-embedding in itself is not inherently problematic.

Chapter 3: The emergence (or not) of center-embedding in iterated sequence learning

3.1. Introduction: The iterated learning model and the emergence of structure

Iterated learning is a process wherein participants are asked to perform a cognitive task, such as viewing and then repeating a sequence, and the results given by one participant become input for the next. The first participant is trained on stimuli such as a string of symbols (e.g. Cornish et al. 2013, 2017), or on a simple artificial language matching strings of syllables to visual stimuli (e.g. Kirby et al. 2008, Beckner et al. 2017). After training, this participant is tested by asking them to repeat back the given string or to label stimuli in the artificial language (without feedback on their correctness). Their results are given as input to a second participant, who undergoes the same learning and testing process, and the same process is repeated for subsequent participants. Each participant's output constitutes a *generation*, and the "genealogy" of outputs taken together constitutes a *chain*.

Through the process of transmission in iterated learning, the initial stimulus is modified due to human learners' cognitive and memory biases, which are amplified with each subsequent generation. Specifically, if the stimulus for the first user (generation 0) is initially random and structureless, it tends to develop structure through repeated transmission. Arbitrary artificial languages develop compositionality and regularity through transmission (Kirby et al. 2008, Beckner et al. 2017, Kirby 2014) and nonlinguistic symbol sequences develop hierarchical structure (Cornish et al. 2013). The present experiments sought to elicit center-embedded patterns, and observe how they were changed through transmission, in a similar paradigm.

Cornish et al. (2013) present an account of the emergence of hierarchical patterns in nonlinguistic strings, using a procedure based on the electronic game "Simon," in which the player views and re-enters sequences of colored lights on a light up panel in the same order as the original sequence. Generation 0 stimuli consisted of a random string of lights in four colors (red, blue, green, yellow). Participants were shown sequences one light at a time, and asked to re-enter that sequence using a button for each color. The first participant's response (i.e. the

sequence of lights corresponding to the buttons they pressed, displayed on the same Simon interface) was then presented as a stimulus to the next user, and so on for ten generations. Over several generations, learners imposed structure on the sequences of flashing lights, eventually producing hierarchical structure (Figure 3.1). This also correlated with an increase in similarity across generations, indicating that the strings were becoming more learnable.

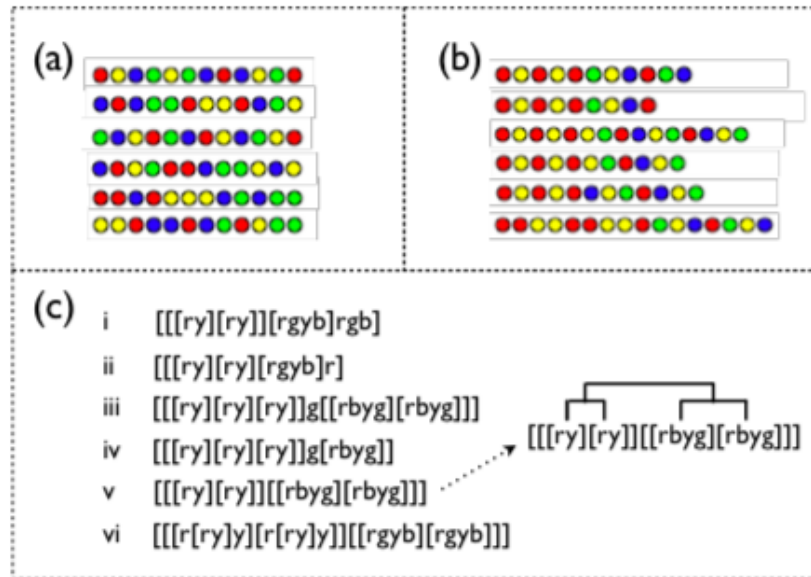


Figure 3.1: Initial (a) and final-generation strings (b) from Cornish et al. (2013), with structures of some final-generation strings (c)

The resulting strings include structures of the form $(A^n B^n)$, which could be identified as the output of a center-embedding grammar, such as (1), a substring from generation 10 (from vi in Figure 1c):

1. [R [R Y] Y]

However, as Cornish et al. (2013) acknowledge, the interpretation of these strings is uncertain. Analysis of strings like these faces the same interpretive problem as do e.g. the results of Gentner et al. (2006) on pattern learning by starlings (see Chapter 5.2.2.1 for a summary): a string like AAABBB could be generated or interpreted by comparing the length of two sets, with no center embedding rules necessary (Rogers & Pullum 2011). In order to demonstrate clearly

the use of recursive center-embedding rules, a different type of string would be required – one which instantiates what Heine & Kuteva (2007:266) call “mirror recursion,” wherein string elements are matched from the inside out, such as the stimuli used in the second experiment of Abe & Watanabe (2011), as discussed in Section 5.2.2. An example would be a palindrome (“Able was I ere I saw Elba”), in which the first character matches the last, the second matches the penultimate, and so on, or a partially palindromic string with nested pairs of matched characters (e.g. $AxBzA$, where the lowercase x , y , and z can be strings of zero or more characters). In the present experiments, this dependency simply took the form of an identical pair of icons (see Chapter 5.0 for more on different types of dependencies in nonlinguistic sequences).

There is prior work (e.g. Abe & Watanabe 2011) suggesting that long-distance dependencies are a necessary precursor to center-embedding. A finite-state grammar can process long-distance dependencies of arbitrary length, and these dependencies are a necessary but not sufficient condition for nested embedding (Rogers & Pullum 2006). A grammar of this type, however, cannot handle sequences with multiple nested dependencies. Thus, the formation of center-embedded patterns in sequences can be taken to indicate the emergence of a context-free grammar.

In addition, there is evidence that it is possible for center-embedded patterns to be implicitly inferred and generalized to greater depths of embedding. McCoy et al. (2021), whose study was conducted and published after my own experiments had concluded, showed that participants are capable of generalizing from two levels of center-embedding in written nonlinguistic (nonsense syllable) strings to deeper levels of embedding in a recognition task. Participants were shown “sentences in an alien language” which consisted of bracketed pairs of matching syllables such as those in (2):

2.

gri klo
vi zin som fo
id brin gri klo plom ot

Syllables in the first half of the string (e.g. gri, vi) were termed category A and those in the second half (e.g. fo, klo) category B. The syllables forming dependency pairs were of identical length and consonant-vowel structure; furthermore, all A syllables had the vowel *i* whereas all B syllables had *o*, providing clear cues to match them. Participants were shown text sequences (one word at a time) with one or two levels of embedding in the artificial language, and then asked to evaluate whether strings – including some with deeper levels of embedding than those shown in training – were possible “sentences.” At the testing phase, sequences were shown in their entirety, to mitigate memory limitations (McCoy et al. 2021: 2227). Subjects performed significantly better than chance at correctly identifying new sequences, including those with greater embedding depth, and rejecting ungrammatical sequences that were the same length as grammatical ones.

To build on the results of studies like Cornish et al. (2013) and apply the insights of iterated learning to center-embedding specifically, I conducted a series of iterated learning experiments that attempted to elicit the emergence of embedded/palindromic structures. As an attempt to prompt the formation of embedded structures, the generation 0 strings in one condition contained a repeated instance of the first icon in the second half of the string (see Figure 3.2).

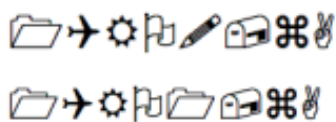


Figure 3.2: Comparison of no-repeat (above) and repeat string (below) from Experiment 1

The first icon in the string was selected for duplication due to the salience effect of first mention (Gernsbacher et al. 1988), and the resulting structure also resembles various long-distance (non-embedded) dependencies between the left periphery and sentence-internal positions in natural language. It was hypothesized that this inclusion of a dependency might prompt further repetition of icons at some stage in the transmission process, possibly including center embedded matched pairs, e.g. strings of the form $AxByBzA$ (see description above). As mentioned previously, the occurrence of long-distance dependencies, such as the pair of identical icons in a repeat string, is a necessary but not sufficient condition for nested embedding (Rogers & Pullum 2006). The formation of additional nested dependencies beyond the first could constitute a transition from a finite-state grammar (which can produce single dependencies) to a context-free grammar, which is required to represent embedding of arbitrary depth.

3.2. Experiment 1: repetition and display mode

3.2.1. Methodology

3.2.2.1. Participants

The human participants for this study were Mechanical Turk workers undertaking the study voluntarily for a small payment (\$3 per task). A pre-study questionnaire ensured that participants were fluent English speakers (it did not ask about competence in other languages), had normal or corrected-to-normal vision, and were using a browser capable of displaying the symbol font used. For each of four conditions (discussed below), four chains of ten participants were employed ($n = 40$). Their responses are referred to as generations 1 through 10.

3.2.2.2. Materials

The initial (generation 0) stimuli consisted of strings of eight icons from the Wingdings font, with the criterion that all icons in a string were different for the non-repeat conditions. This icon lexicon was chosen so as to avoid icons that were too visually similar and hence confusable. The same set of randomized initial strings was used across both sequential and simultaneous presentation modes and all chains (see under 4.2.2.3 below for more details on the conditions).

Nonlinguistic icons were used because letters or syllables could result in participants chunking characters into strings resembling words or acronyms (cf. Cornish et al. 2017), creating patterns that could interfere with the development of structure and thus confounding the results. Digits might likewise be subject to chunking, e.g. the creation of culturally meaningful numeric strings such as *1776* or *911*. Unrelated icons, such as sunbursts, hands, computers, and the like, lend themselves less easily to the chunking strategy.

In non-repeating strings, all icons in the initial string were different. In repeating strings, the first icon replaced a randomly selected icon in the second half of the string (i.e. fifth through eighth symbol). Otherwise, all strings in the initial set were the same in repeat and no-repeat conditions.

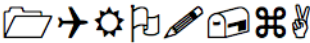
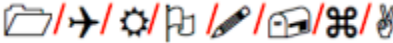
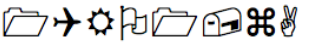
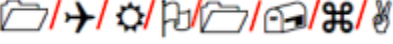
Using a larger lexicon of icons than the four-color set of Cornish et al. (2013) also allowed strings to be truly structureless (i.e. all symbols are different) at the beginning, and may decrease formation of structures by chance. A larger variety of symbols may also remove a confound present in Cornish et al.(2017): spatial influence from the keypad layout (Kenny Smith, p.c.), which caused participants to frequently produce sequences following the keypad clockwise or counterclockwise. With a larger keypad (4 by 4; see Figure 3 below), spatial relations are less salient (see also Jiang et al. 2018, discussed in Section 3.2.3.2, on the use of different spatially oriented displays in sequence-learning experiments with nonhuman primate

subjects). Searching for keypad patterns (e.g. rows, columns, four-key blocks) within the data revealed that keypad-influenced patterns were not common.

3.2.2.3. Design

This experiment used a 2 x 2 design: two display modalities and two different types of initial string; see Table 3.1 below for the resultant conditions.

Table 3.1: The four conditions in Experiment 1.

simultaneous no-repeat  4 sec display of whole	sequential no-repeat  1 sec display of each symbol
simultaneous repeat  4 sec display of whole	sequential repeat  1 sec display of each symbol

The first factor (simultaneous vs. sequential presentation) was designed to address the question of whether writing aids significantly in the development of embedded structures through iterated transmission, as postulated in some accounts of diachronic language change (e.g. Kalmar 1985), and supported by observed differences between syntactic complexity in writing versus spontaneous speech (Miller & Weinart 1998, Karlsson 2020; see also Chapter 2.3). This hypothesis was tested by using both simultaneous and sequential modes of presentation and input with the same stimulus strings, in order to approximate spoken versus written language transmission. The simultaneous display mode is analogous to the permanence of writing, whereas the sequential display mode is analogous to the rapid fading of real-time speech or sign, where a processing bottleneck occurs.

In simultaneous presentation mode, participants viewed an entire string of icons at once (for four seconds), and were able to view the string they entered incrementally as they re-entered it. In the sequential conditions the string was presented one icon at a time (one

second duration per symbol with a 100 ms inter-stimulus interval) and when icons were re-entered by the participant, entering an icon overwrote the previous one (a counter kept track of the number of icons entered).

In addition, a second factor was tested: whether or not seeding the generation 0 strings with a repeated icon would lead to additional levels of embedding. For repeat strings, the first icon of the string replaced one randomly-chosen icon within the second half of the string. This created a long-distance dependency (of varying length) which, by hypothesis, might prompt further repetition of icons at some stage in the transmission process, possibly including center embedded dependencies (see introduction to this section, and Abe & Watanabe 2011). Conversely, the no-repeat conditions shed light on whether structure appears “autonomously,” that is, without using repetition as a prompt, or whether an existing dependency is required to act as a “seed” for further embedded strings.

3.2.2.4. Procedure

The first participant of each chain viewed twenty randomized strings (identical for all initial participants) of eight icons each. After viewing each string, participants were instructed to re-enter it using a keypad (Figure 3.3) with all the included icons and press an enter button when they had re-entered the full string.

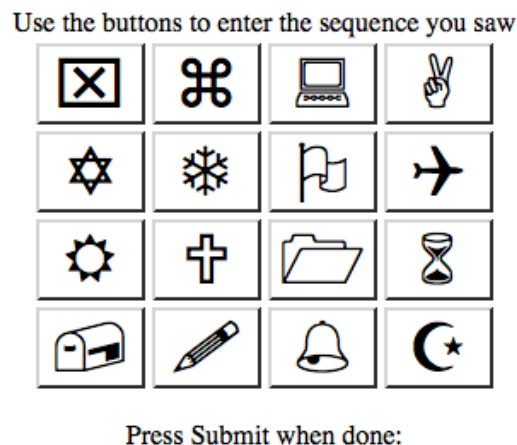


Figure 3.3: The input keyboard, with the entire icon lexicon

If the entered string was fewer than six icons in length, the user was prompted to view and re-enter the string, and the too-short string was not saved. This enforced minimum prevented string length from decreasing too drastically. The input of the first participant was copied and re-posted for a second participant, and so on through the chain of ten.

3.2.2.5. Analysis

Data were analyzed with regard to changes in quantitative variables over generations, including similarity to previous generation (as an index of learnability), length of the strings, and level of center-embedding: center-embedded structures were located and their depth of embedding was quantified.

Length was simply measured by the number of icons in the string. Similarity was calculated by taking the Levenstein edit distance between two strings (the number of icon additions, deletions, or replacements needed to change one into the other), normalizing it (dividing by the length of the longer sequence) and subtracting the result from 1. This metric was used to compare a string to its parent in the preceding generation, and indicates the learnability of a sequence.

To discern center-embedding, all participants' responses were searched for the longest substring (if any) of three or more characters beginning and ending with the same character, i.e. of the form A...A (note that this substring may be the whole string). A minimal embedded string, therefore, would have the structure ABA. If a substring of this form was found, it was then subjected to a further analysis: the string of icons between the identical “bracketing” characters was searched for another substring of form B...B, and so on until no more such strings were found. The number of nested “bracket” icon pairs found constituted the embedding depth of the string. For example, the string ABCCBA has an embedding depth of two; the inner pair CC does not count as a layer of embedding since it does not “bracket” another character. The process is shown in Figure 3.4.

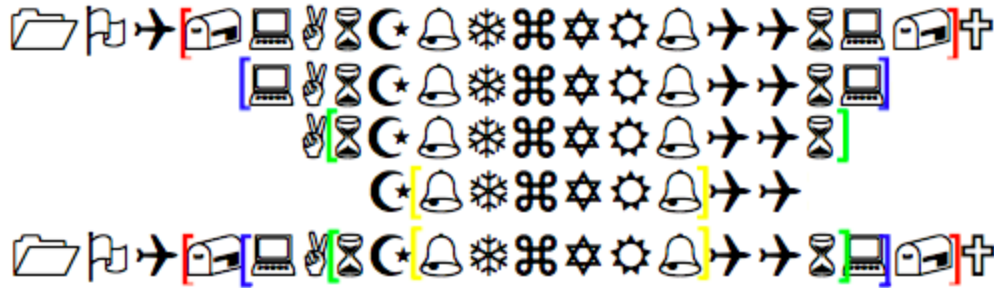


Figure 3.4: Finding center-embedding on a string of embedding depth 4

It is possible that center-embedded strings may be attributed to chance – the result of participants pressing buttons at random, rather than the emergence of a recursive pattern. In order to compare actual rates of embedding to those expected by chance, across chains, 1000 "pseudo-chains" were created for each real chain in which each string was randomly permuted (thus preserving icon frequencies while randomizing structure). Then the quantile of the real average value for each chain was found. A quantile of below 5% was considered below chance, and one above 95% was considered above chance.

Statistics for these variables were analyzed using a linear mixed effects model, in which generation and conditions (for display mode and repetition) were fixed effects, and chain as a random effect. The total number of strings analyzed was 3200 (4 chains * 4 conditions * 20 strings * 10 generations).

3.2.3. Results

Across all conditions there was a general decrease in length (Figure 5), though some individual strings also grew longer. Many strings, which all started out at eight icons in generation 0, shortened in length to the 'floor' of six icons – the minimum allowed length, below which a participant would be required to redo the string.

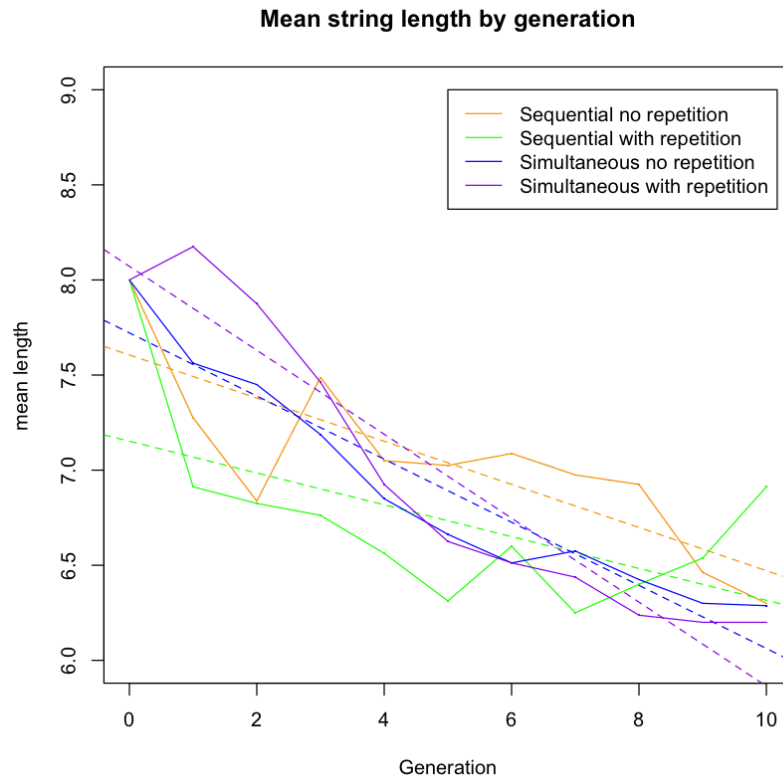


Figure 3.5: Mean length of strings over generations, experiment 1.

The length of the strings in the sequential display mode showed more variation (in both the repeat and no-repeat conditions), probably because users had more difficulty tracking the number of icons they had seen. String lengths in simultaneous display mode decreased significantly ($R^2 = 0.4206$, $p < .001$) more than in sequential display mode. The average of the slopes for the simultaneous display conditions (blue and purple in Figure 3.5) was -0.193 , while the average of the slopes for the two sequential display conditions (orange and green in Figure 3.5) was -0.0985 . No significant differences in slope were observed between chains within any condition, nor between repeat and non-repeat conditions.

Trends for similarity are graphed in Figure 3.6. Across all conditions, similarity showed a significant increase ($R^2 = 0.1207$, $p < .05$), although as shown by the trendlines, it did not increase monotonically at every generation. Strings in the simultaneous display conditions

showed a numerically faster increase in similarity than in the sequential display condition that was, however, not significant: the slope of the linear regression for the simultaneous repetition condition was the highest at 0.03853, and the average slope for the simultaneous display conditions was 0.028, while that of the sequential display conditions was 0.0199.

No significant differences, however, were found among either the four conditions or among chains within any condition. In a mixed effects model comparing similarity scores at generation 10 (similarity to generation 9) and generation 1 (similarity to the initial random strings), no significant differences were found between conditions.

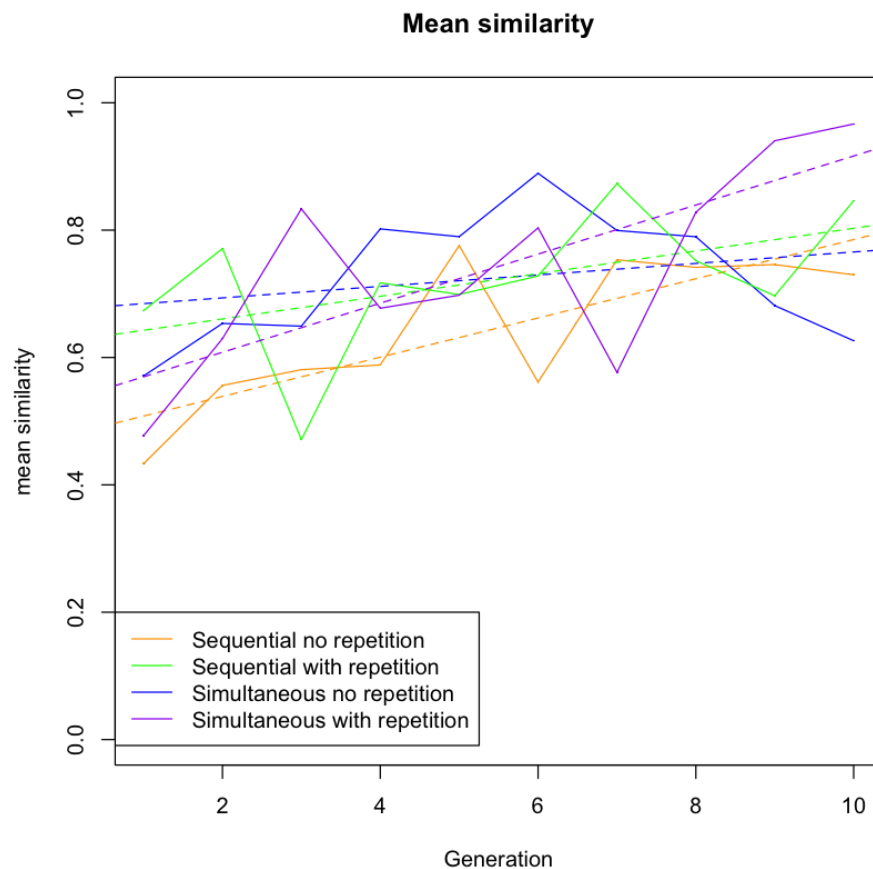


Figure 3.6: Similarity of strings in each generation to their predecessors, Experiment 1.

There was a general (but not always monotonic) increase in embedding depth with each generation in the sequential display conditions, whereas embedding did not show such sharp upward trends in the simultaneous display condition (Figure 3.7). Comparison of linear mixed effects models showed that this effect of display modality was significant ($X^2(7) = 70.744$, $p < .0005$).

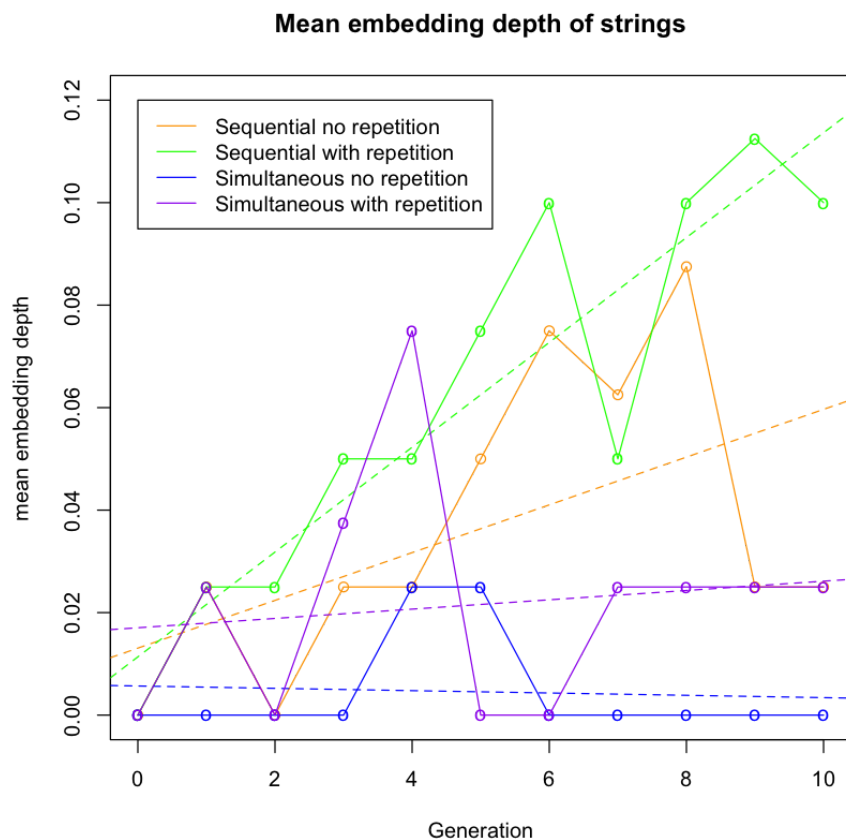


Figure 3.7: Average embedded string depth over generations in Experiment 1

Comparison to chance using the method discussed under Analysis (4.2.2.5 above) confirmed that the actual embedding depth in most chains was near or below chance. Only two chains in the sequential repeat condition and one in the simultaneous repeat condition showed greater than expected chance values: i.e., their average embedding values were higher than at

least 95% of chance results. As a result, the actual mean embedding value for the sequential repeat condition was greater than chance overall, though that of the simultaneous repeat condition was lower.

3.2.4. Discussion

These results confirmed that novel center-embedded structures can emerge through iterated learning of initially unstructured sequences, but not necessarily at rates higher than chance. There were surprising differences between simultaneous and sequential presentations of stimuli. Contrary to the claim that writing fosters the development of embedding (emulated by the simultaneous display condition), center-embedding was actually far more prevalent in the sequential condition, which was designed precisely to emulate the impermanence of spoken or signed forms of language. The relative absence of embedding in simultaneously displayed strings is also surprising given the appearance of similar palindromic and symmetrical patterns in sequences of emojis online, and the broader importance of mirror symmetry in many areas of visual art, as discussed in Chapter 3.1.5. This result may have been due to the tendency of simultaneously displayed strings to shorten more than those displayed sequentially, and their greater increases in similarity from generation to generation (i.e. the strings tended to stabilize more in simultaneous display mode). In addition, as discussed below, the “floor” of six icons was too low.

On the other hand, the greater frequency and depth of embedding seen in sequential display mode may be attributed to cognitive bottleneck effects. A long string of icons, shown one at a time for a second each, places a burden on working memory. Consequently, this mode of display may be conducive to the formation of structures – embedded and otherwise – as a memory aid.

In light of these considerations, all subsequent experiments were carried out with two parameters different from the first: participant response length was fixed to match stimulus

length (as discussed below), and only sequential display mode was used. The latter change was introduced because sequential display mode produced more variation in the results, and strings were less likely to “fossilize” at the shortest possible length.

In Experiment 1, strings could vary in length, with a floor of six icons: if a user submitted a string shorter than six icons, they were required to redo the string. This variation in length allowed some strings to drop to a length of six and effectively “fossilize” there, a factor which seemed to impede the development of embedding, as a string of six different icons is short enough to be held in short-term memory without much difficulty. There was no upper limit on length, and some strings expanded to as long as 18 or 20 symbols, although across all chains and conditions there was an average decrease in length. Therefore, in subsequent experiments, participants' response length was fixed to match that of the stimuli, as described below under Procedure (4.3.1.4.). In Experiment 2, I set out to examine the effect of fixing string length with and without repeat icons.

3.3. Experiment 2: Fixed length with repeats

This experiment was a replication of the sequential-display condition in Experiment 1, but with length fixed. Strings were of length eight. Prior experimentation indicated that these conditions were optimal for the formation of center-embedding: length fixed at eight icons, repeated icons in the participants' responses (but no other pre-existing structure), and strings shown in sequential display.

3.3.1. Methodology

3.3.1.1 Participants

For this experiment, there were two conditions: repeat and no-repeat, as in Experiment 1 (both displayed in RSVP mode). For each condition, five chains of ten subjects were employed ($n = 100$).

3.3.1.2 Materials

The initial stimuli, as before, consisted of 20 strings of eight icons from the Wingdings font, with the criterion that all icons in a string were different (for structureless strings). As before, there were 16 visually distinct icons. The icons used were the same as in Experiment 1, except that one was replaced: a sunburst was replaced by a pair of scissors to avoid confusion with other radial-shaped icons (such as a snowflake), which previously may have been a confound.

3.3.1.3. Procedure

The basic procedure was the same as in the prior experiment, except that each icon was displayed for 1100 ms, instead of 1000 ms as in Experiment 1. String length was fixed at eight icons (the length of the generation 0 strings); this was implemented by having the keypad become invisible and automatically advancing to the next string as soon as eight icons had been entered.

3.3.1.4. Analysis

Embedding depth and similarity were measured as in Experiment 1. The total number of strings analyzed was 2000 (2 conditions * 5 chains per condition * 10 generations * 20 strings). All variables in Experiment 1 were analyzed in the same way, except for length, which was fixed.

3.3.2. Results

Figure 3. 8 shows similarity scores over the generations. There was no significant increase in learnability in the no-repetition condition ($B = -.0007$, $SE = 0.12$, $p = .6$); conversely, learnability did increase in the repetition condition ($B = .017$, $SE = .007$, $p < .05$).

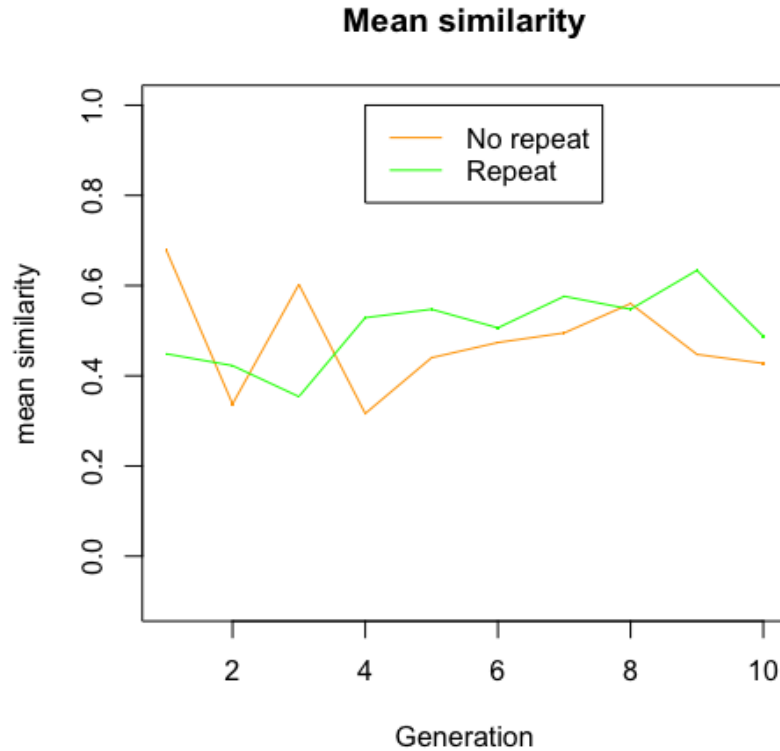


Figure 3.8: Similarity of strings in each generation to their predecessors, experiment 2.

More embedding appeared in the repeat condition than the no-repeat condition, and this effect was significant as determined by mixed effects models ($B = .11$, $SE = .05$, $p < .05$). Figure 3.9 shows how embedding depth slightly (but significantly) increased over the generations ($B = .03$, $SE = .005$, $p < .005$), with a slightly faster increase in the repeat condition and an uptrend toward the end in the no-repeat condition. Embedding, however, was not significantly greater than chance in any chain; in three chains (out of five) of the no-repeat condition and two of the repeat condition, it was actually significantly less than chance (i.e., actual values fell within the bottom 5% of randomized values).

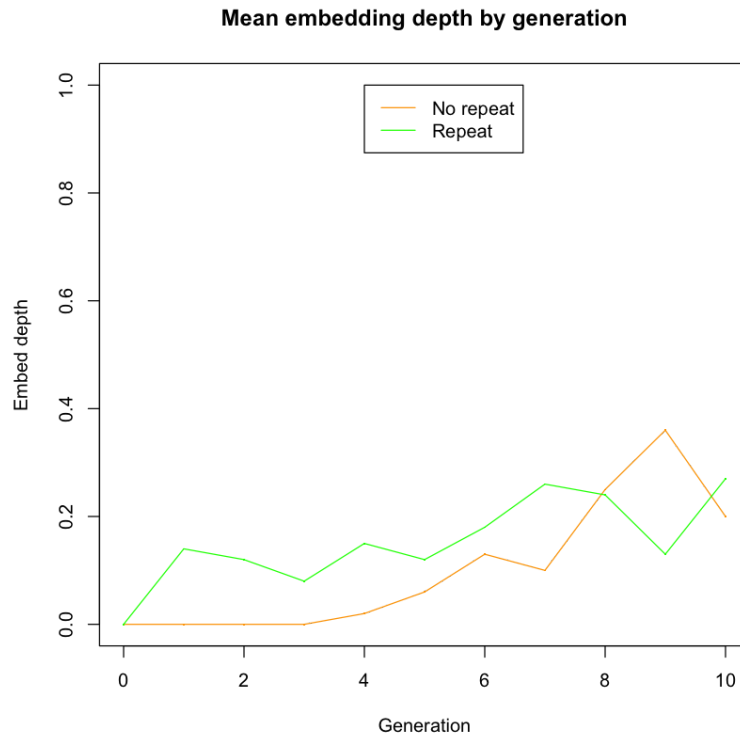


Figure 3.9: Average embedded string depth over generations in Experiment 2.

3.3.3. Discussion

Experiment 2 was designed to replicate only those conditions in Experiment 1 which seemed most conducive to the formation of embedding, but with fixed length (since allowing string length to decrease across generations seemed to impede the formation of embedding). However, despite (marginally) higher rates of embedding in the repeat condition than in the no-repeat condition, rates were not significantly greater than chance overall. Therefore, Experiment 3 approached the issue of center-embedding in sequence learning from another angle: starting out with a mixture of random and prestructured strings at Generation 0, in order to assess how the structures proliferate, change, or vanish.

3.4. Experiment 3: attrition and mutation of structure

In this experiment, the strings at generation 0 contained a mixture of random and structured strings; these structures were center-embedded/palindromic (ABCDDCBA) in one of the between-subjects conditions, and doubled (ABCDABCD) within the other. The latter configuration could be interpreted as exemplifying crossed dependencies. Prior sequence-learning experiments (Uddén et al. 2012) have found that crossed dependencies were more easily learnable than center-embedded patterns. However, Uddén et al. used dependencies consisting of arbitrary pairs of letters with no clear perceptual similarity between dependency elements, so it is not certain that participants were consistently recognizing the pattern. Öttl et al. (2015), in a similar experiment with alliterative pairs of syllables as dependencies, found no difference in learnability between crossed and center-embedded patterns. Moreton et al. (2021), published after this experiment was conducted, tested the learnability of palindromic and repeat patterns of meaningless syllables in auditory memory. Participants listened to sequences of syllables that were either palindromic (such as “ko li ve su ve li ko”) or reduplicative (“ko li ve su ko li ve”), without being explicitly told what the pattern was, and then asked to identify whether a novel sequence conformed to the learned pattern. Performance was significantly better, and reaction times shorter, in the reduplication condition. (See Chapter 4 for a comparable experiment involving meaningful artificial language sequences.) The current experiment used stimuli similar to those of Moreton et al. (2021), in a visual icon paradigm like that of the previous experiments discussed in this chapter.

A mixture of structured and unstructured strings was used to explore possible effects of iteration. It was hypothesized that if participants were exposed to a regular pattern frequently, this pattern would become predominant, spreading to strings that were originally unstructured (see Hudson Kam and Newport 2009 for experimental evidence of this process in a meaningful artificial language). Conversely, participants might be expected to modify difficult patterns into

ones that are easier to process, meaning that center-embedding may be attrited or reconfigured into a less-demanding structure. The latter is what emerged in the results.

3.4.1. Methodology

3.4.1.1. Participants

The participants in this study were Mechanical Turk workers undertaking the study voluntarily for a small fee (\$5 per task). A pre-study questionnaire ensured that participants were fluent English speakers, had normal or corrected-to-normal vision, and were using a browser capable of displaying the symbol font used.

For each condition, four chains of ten generations each were carried out, for a total of 80 participants. Each participant performed 20 trials, so the total number of strings analyzed was 1600.

3.4.1.2. Materials

The initial generation 0 stimuli consisted of 20 strings of eight icons from the Wingdings font. The same set of icons used in Experiment 2 was used. In both conditions, Generation 0 consisted of 60% structured strings and 40% unstructured strings. In one condition, the structured strings were center-embedded (ABCDDCBA); in the other, they were doubled (ABCDABCD). Examples of structured sequences are shown in Figure 3.10.



Figure 3.10: structured strings (top: embedding, bottom: doubled), from experiment 3.

Unstructured strings, constituting 40% of each Generation 0, were created by shuffling icons within the doubled or center-embedded strings. This resulted in structureless strings with the same frequency distribution as the structured ones (additionally filtered to ensure that no

doubled or palindromic structures are found in the strings). Each set of 20 strings at Generation 0, therefore, consisted of 12 structured strings and 8 unstructured.

3.4.1.3. Procedure

The procedure followed in this experiment was the same as in Experiments 1 and 2.

3.4.1.4. Analysis

Two structural parameters were measured in order to assess the preservation and spread or attrition of initially present structures: embedding depth and length of longest repeated substring. The longest repeated substring in a string was measured by taking all substrings of the string and identifying the longest one that occurred more than once. For example, in the string ABCDEABC, the longest repeated substring would be ABC, of length 3; in the doubled string ABCDABCD, the longest repeated substring is ABCD.

4.4.2. Results

There were no significant differences in learnability of the Generation 0 strings between conditions, measured by similarity scores at Generation 1 ($t(157) = .43$, $p = .67$). Nor did similarity increase over generations (Figure 3.11), and there were no differences between conditions in this respect (all $p > .6$). Within-subject analysis in each condition however showed differences in learnability between structured and random strings. In the mirror condition, mirror strings were slightly less accurate than random ones, but not significantly so. In the doubled condition, doubled strings were significantly better replicated than the random ones ($t(52.144) = 5.6281$, $p < .005$).

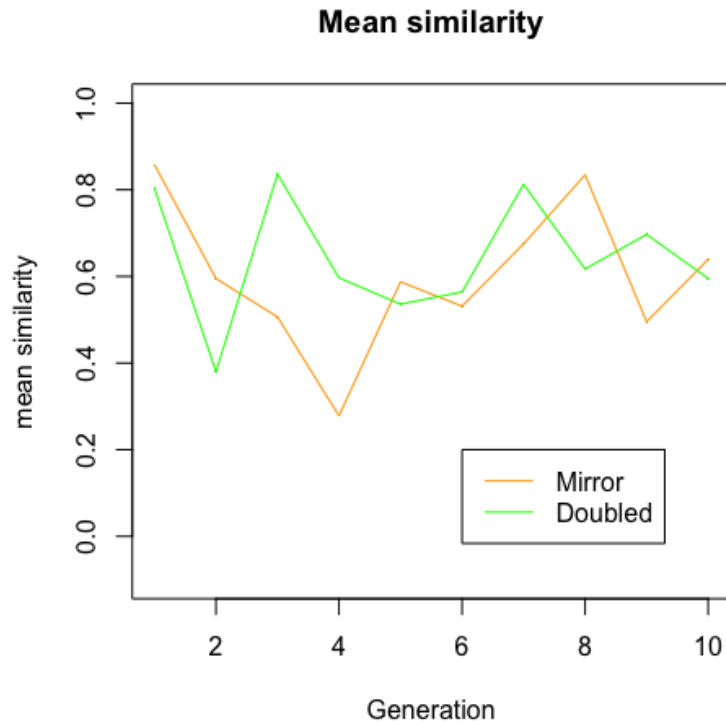


Figure 3.11: Average similarity of strings in each generation to their predecessors, by condition, experiment 3.

Both structural parameters which were measured, namely embedding depth (Figure 3.12) and length of longest repeated substring (Figure 3.13), decreased over generations. Embedding depth decreased sharply in the mirror condition ($R^2 = .63$, $F(1,9)=18$, $p < .005$). In the doubled condition, it was low throughout but still showed a significant decrease ($R^2 = .46$, $F(1,9)=7.815$, $p < .05$). Similarly, length of repeated substrings decreased significantly in the doubled condition ($R^2 = 0.4652$, $F(1,9)=9.699$, $p < .05$); this parameter stayed low in the mirror condition throughout without a significant decrease, indicating that doubled strings did not form as a transfiguration of an embedded (mirror) structure.

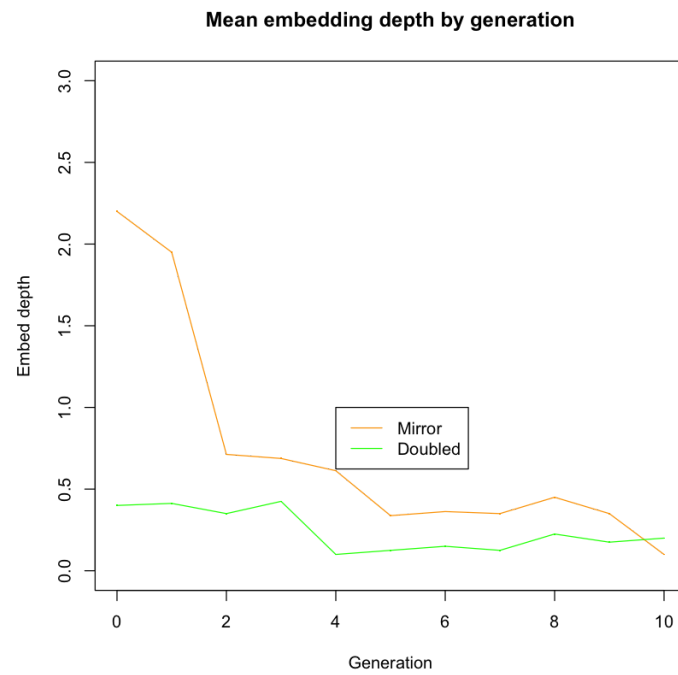


Figure 3.12: Average embedded string depth over generations in Experiment 3

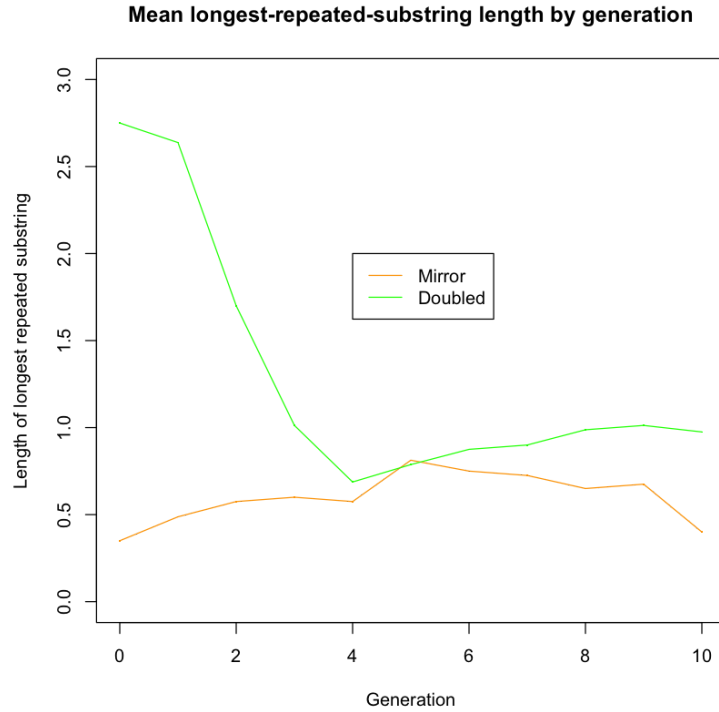


Figure 3.13: Mean length of longest repeated substring over generations in Experiment 3

3.4.3. Discussion

This experiment further confirmed the difficulty of learning center-embedded strings and the rarity of center-embedding in strings generated by participants through iterated learning. At the first generation, there did not seem to be a clear difference between the overall between-subjects learnability of doubled and center-embedded strings, although the within-subjects analysis showed differences from random strings. Specifically, the learnability of center-embedded strings was no better than that of random strings, whereas doubled strings were learned significantly better than random ones. This result is consistent with some earlier work on the difficulty of center-embedded sequences (Conway et al. 2003) and learnability of crossed versus nested dependencies (Uddén et al. 2012). However, doubled string structure generally underwent attrition as well. The parameters of this sequence-learning task – rapid sequential display – might have made it harder to notice patterns in a subset of strings, and once the patterns had vanished, they did not re-emerge.

3.5. General discussion

In this series of iterated learning experiments, I set out to determine whether center-embedded structures can appear in initially unstructured, random strings of nonlinguistic icons, and under what circumstances. While embedded structures did appear, they rarely showed up at more than chance rates, but there were (sometimes significant) differences between conditions. Specifically, repeated icons in initial strings did seem to prompt the formation of embedding, whereas if the initial strings had no repetition, embedding was less prevalent or occasionally nonexistent. This suggests that these dependencies are a necessary, though not sufficient, condition for nested embedding, and provide a possible way for a finite-state grammar, which allows single dependencies, to develop into a context-free grammar (Rogers & Pullum 2006).

Experiment 2 was designed to replicate only those conditions in Experiment 1 which seemed most conducive to the formation of embedding, but with fixed length (since allowing string length to decrease across generations seemed to impede the formation of embedding). However, despite (marginally) higher rates of embedding in the repeat condition than in the no-repeat condition, rates were not significantly greater than chance overall.

Since structured strings generally did not emerge as expected, the third experiment was designed to test whether center-embedded (and doubled) strings were learnable as such, and whether structure spread to other strings or was attrited. The lower learnability of such structures was confirmed, although doubled string structure did not disappear as fast, as measured by the existence of long repeated substrings. A discrepancy between doubled and center-embedded strings also occurred, in which the former were found to be easier to replicate.

One potentially relevant factor not addressed in these experiments was the role of language experience in nonlinguistic sequence learning. There is evidence that native language word order may influence working memory for sequences (Amici et al. 2019). Specifically, speakers of languages with preferentially head-initial order, such as Thai and Italian, were better at remembering initial components of visual sequences, whereas speakers of head-final languages like Japanese and Korean performed better on the ends of sequences. Whether speakers of languages with a higher prevalence of center-embedding (e.g. Japanese, Korean; see Chapter 2 for corpus details) are better at memorizing or generating center-embedded nonlinguistic sequences than speakers of SVO languages like English (like the participants in the experiments reported in this chapter), which are less tolerant of center-embedding, would be an interesting avenue for further inquiry.

In summary, center-embedding patterns did occur in this nonlinguistic sequence learning task, but not above chance, and these patterns seem to be more difficult to learn than doubled strings. The “long-distance dependency” between two identical icons in a Generation 0 string does seem to foster more embedding, as seen in Experiment 1. This observation is consistent

with the idea that long-distance dependencies are a prerequisite for deeper levels of embedding (Abe & Watanabe 2011). When center-embedding is presented in some of the Generation 0 strings, it is lost in transmission. All of these results are consistent with the general disfavorment of center-embedding in language, and the role of working memory constraints therein.

However, sequence-learning experiments that employ strings of letters or icons do not capture an important aspect of natural language: the presence of semantic meaning. In the next chapter, I discuss artificial grammar learning, and present the results of two new experiments involving meaningful artificial languages that exemplify different dependency structures.

Chapter 4. The learnability and emergence of dependency structures in an artificial language

4.1. Background: linguistic dependencies

Long-distance dependencies between constituents – e.g. between a subject and verb – are an essential aspect of human language and can be structured in different ways. Dependencies can be branching, center-embedded, or (rarely) crossed, as explained below. In natural languages, branching dependencies are generally, but not always, more prevalent than center-embedded dependencies, with variations in the range of phrase types which allow center-embedding (Hawkins 2004: 128). The third type, crossed or cross-serial, is rare in natural languages and the most computationally complex according to the Chomsky hierarchy (Chomsky 1963, Hunter 2021) – but there is some experimental evidence that this structure is easier to learn and process than center-embedded dependencies (Bach et al. 1986). Artificial language learning experiments (e.g. Culbertson 2012, Fedzechkina 2018) can shed light on the cognitive factors shaping language typology – for example, whether the prevalence of branching over center-embedded dependencies reflects greater learnability¹ of the former relative to the latter. In order to explore how learnability reflects syntactic typological tendencies for dependency ordering, we ran two experiments, testing the learnability of different dependency types using nested locative NPs in an artificial language (Experiment 1), and the emergence of consistent dependency structure in iterated learning (Experiment 2).

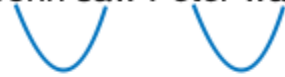
4.1.1. Three ways of arranging dependencies

There are three logically possible ways of arranging multiple dependencies. Figure 4.1 shows examples of the three dependency types between a subject noun and its verb: branching (in this case right-branching), center-embedded, and crossed.

¹ Throughout this paper, we use the word *learnability* to mean “how easily a given structure can be learned by humans.” This is different from the notion of learnability in mathematical linguistics, which is concerned with which formal classes of languages can be learned by particular learning algorithms (see for example Gold 1967).

a. (Right-) branching dependencies in English:

... when John saw Peter walk



b. Center-embedded dependencies in German:

... als Johan Peter laufen sah



c. Crossed dependencies in Dutch:

... toen Jan Peter sag lopen



Figure 4.1: Comparison of dependency types with English, German, and Dutch examples, after Vosse & Kempen 1991. All sentences are glossed “when John saw Peter walk.”

4.1.1.1. Branching

Branching dependencies can be schematically represented as A1 A2 B1 B2; that is, each dependency (between A1 and A2, between B1 and B2) is resolved before the subsequent one is opened. In right-branching dependencies, the head of the phrase comes before its dependent; in left-branching dependencies the reverse is true. A simple example of English right-branching dependencies is shown in Figure 4.1a, and the relative clauses in (1) form a more complex example.

1. Jack walked the dog [which worried the cat [which chased the rat [which ate the malt]]].

English possessive NPs are left-branching, with the head noun on the right:

2. Jack's [friend's [cat's [mouse]]]

4.1.1.2. Center-embedding

Center-embedding refers to a linguistic structure wherein a dependency (B1-B2) is embedded inside another (A1-A2) of the same type, such that the components of A are on

either side of B. Thus, the dependency structure would be A1 B1 B2 A2. This differentiates center-embedding from branching. Figure 4.1b shows an example from German, and 3 shows center-embedded relative clauses in English:

3. a. The rat [the cat chased] ate the malt
- b. The rat [the cat [the dog worried] chased] ate the malt
- c. The rat [the cat [the dog [Jack walked] worried] chased] ate the malt

4.1.1.3. Crossing

In addition to left and right branching and center-embedding, subject-verb dependencies can also be crossed (Figure 4.1, example C). In this pattern, the first elements of all dependencies are concatenated, and the second elements are in the same order (A1 B1 A2 B2). This phenomenon is rare in natural languages; few examples are attested, specifically Dutch, Swiss German (Schieber 1985), and Tagalog (MacLachlan & Rambow 2002). A complex example from Dutch is shown in Figure 4.2, illustrating the crossed dependency pattern that appears in subordinate clauses with infinitives (Bresnan et al. 1982).

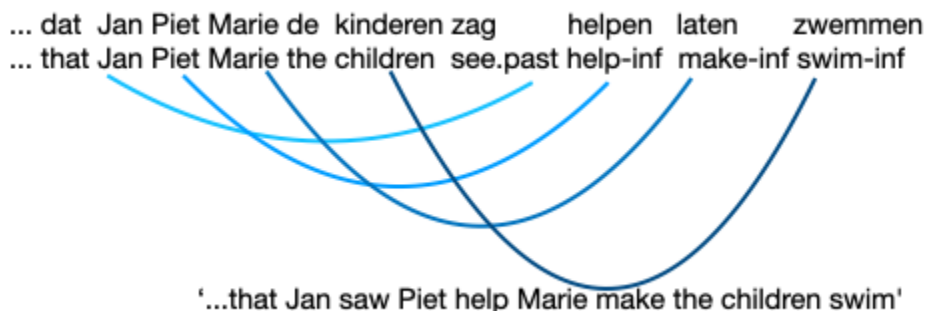


Figure 4.2: Complex Dutch sentence with crossed dependencies, after Bresnan et al. 1982

In some Dutch dialects, crossed dependencies between infinitive verbs and their subjects are grammatical while equivalent center-embedded ones are ungrammatical, and in others, both are allowed but crossed dependencies are more common (Steedman 1984: 52). Crossed noun-verb dependencies also occur in Swiss German (Huybregts 1984), and in the Austronesian language Tagalog (MacLachlan & Rambow 2002), the official language of the

Philippines. Here there is a crossed dependency between the sentence-initial verbs and their argument nouns:

4. [Nagisip [na bumili si Pedro ng bulaklak]]
AT.thought LK AT.buy NOM Pedro flower
'Pedro thought to buy (of buying) a flower.' (LK = linker, AT = agent topic)

Generally speaking, center-embedded dependencies are more common than crossed dependencies in natural languages (Fodor 1978). In some cases, both crossed and center-embedded dependency readings of the same sentence can be possible, in which case the center-embedded reading is preferred (Dalrymple & King 2013). There seem to be no languages that allow only crossed dependencies in all types of phrases, or in which crossed dependencies are the default and center-embedded dependencies are exceptional (Steedman 1984: 36).

4.1.2. The cognitive bases of dependency structure: learnability and processing

Several cognitive factors related to learnability and processing may influence the distribution of dependency structures in natural languages, i.e. the prevalence of branching and comparative avoidance of center-embedding and crossed dependencies. Language typology seems in at least some cases to reflect the learnability and/ or processability of different structures, as demonstrated through artificial language learning experiments.

Culbertson (2012) offers an overview of learnability experiments in relation to language universals, which generally show that more typologically common structures are also more learnable. For instance, in one such experiment, Culbertson et al. (2012) trained participants on simple artificial languages with inconsistent mixed rules for the ordering of nouns, adjectives, and numerals, and examined which orders participants produced when asked to label stimuli. The participants' learning biases reflected natural language word-order universals as described by Greenberg (1963), specifically a bias against the combination of adjective-noun and noun-numeral orders, which is rare in natural languages. In addition, while the participants were

all English speakers, they did not preferentially replicate English word order (numerals and adjectives both prenominal). Culbertson et al. (2020) also demonstrated that artificial languages with typologically more common features (“harmonic” word order patterns) are more learnable even for speakers of languages that do not follow the typologically typical order. This tendency for typology to correlate with learnability even holds for cases where the artificial language uses features not found in the subjects’ native languages; for example, speakers of English (which lacks noun case marking but has number marking) and Japanese (which has case marking but no plural marking) both strongly preferred the typologically common ordering of number before case (Saldana et al. 2021).

While learnability is of course not the only factor in language typology-- historical contingency clearly plays a large role-- it is likely one major factor (Culbertson et al. 2012). In addition, processing difficulties may be relevant to typological frequency, either as a factor in themselves or as a “filter” on learnability; i.e., if the input cannot be processed in the first place, it cannot be used as a basis for learning (Kirby 1999). However, as discussed further below, crossed and center-embedded dependencies may form a counterexample to the generalization that the most learnable features will also be typologically common.

4.1.2.1. Dependency length minimization

One specific cognitive factor potentially involved in dependency structure typology is minimization of dependency length. The processing difficulties presented by multiple center-embedding are well-attested (e.g. Blumenthal 1966, Fodor & Garret 1967, Blauberg et al. 1974, Foss et al. 1970) and this difficulty likely arises from working memory load. The fact that written language features more prolific and deeper center-embedding than spoken language (Miller & Weinart 1998; Sakel & Stapert 2010; Karlsson 2007, 2009, 2010; Levison 2014) suggests that these structures pose a difficulty for working memory that is mitigated in writing and/or reading.

This working memory load may be attributed to the length of the dependencies involved: the distance between two syntactically related words (e.g. noun and verb, noun and adposition), and also the number of unresolved dependencies which must be maintained mid-sentence. During on-line sentence processing, multiple center-embedded phrases like 3C above present persistently unresolved dependencies, which challenge working memory more than a right- or left-branching structure (1) in which dependencies are resolved sooner (see Figure 4.1 for an illustration of different dependency lengths). Languages have a general tendency to minimize total dependency length and the number of dependencies open during sentence processing (e.g. Hawkins 1994, Futrell et al. 2015), which often rules out center-embedding, although long-distance dependencies are never eliminated entirely (Liu et al. 2017). Dependency length minimization thus favors right- or left-branching phrases.

Languages have a general tendency to avoid center-embedding (thus lowering dependency length and cognitive load) by selecting combinations of word order parameters that prevent it (Kuno 1974), or by avoiding such orders where they are grammatical. For example, Persian has obligatory extraposition of complement clauses which would otherwise be center-embedded (Dryer 1980), and Japanese has an optional scrambling rule (Lewis & Nakayama 2001). English grammatically permits both center-embedded sentences like 3c and branching dependencies like 1, but the paraphrase 1 is preferred over 3c because it is easier to process.

Kuno (1974) predicts that combinations of word orders forcing center-embedding, such as noun-initial noun phrases with postpositions, should not exist, as it would create a "hopeless situation of center-embedding and juxtaposition of prepositions". However, some natural language data suggest that these constraints are not absolute. Hagege (2010), cites counterexamples from the Nilo-Saharan language Moru, in which just such a "hopeless" pileup of adpositions occurs, and yet is fully acceptable:

5. [kokyε uni [toko dasi [odrupi ma ro] ro] ri] drate
 dog blackness woman main brother 1SG of of of die.PST
 'the black dog of the main wife of my brother is dead' (Tucker 1940: 165)

The corresponding right-branching, non-center-embedded version (with postpositions right after their head nouns) is not grammatical:

6. *kokyε uni toko dasi ri odrupi ro ma ro drate
 dog black woman main of brother of 1sg of die.PST

Other Nilo-Saharan languages show the same pattern (Hagege 2010: 32). The equivalent noun-final order with prepositions is also attested in Ancient Greek:

7.
 to
 the.ACC
 tees
 the.GEN
 tou ksainontos
 the.GEN wool.carder.GEN
 tekhnees
 art-GEN
 ergon
 work-ACC

'The work of the wool-carder's art' (Plato, the Statesman, 281a) (from Hudson 1996)

Hawkins (1994: 8) also notes that SOV word order, as in Japanese, Korean, and Turkish, forces center-embedded clauses; these are grammatical and acceptable, whereas similar sentences in English are generally rejected by native speakers.

Hawkins (1994) proposes a cross-linguistic hierarchy of permitted center-embedding: NP > VP > S (1994: 14), wherein categories that are typically longer and more complex are less embeddable (1994: 23). Natural language data like that cited by Hagege (2010) further suggest, in support of Hawkins' thesis, that whatever cognitive factors make center embedding difficult apply less strongly to NPs than to sentences.

There is also evidence linking learnability to dependency length minimization. Fedzechkina et al. (2018) found that, given an artificial language learning task with long dependencies between words, learners restructured the input to reduce dependency lengths by rearranging the order of short and long constituents, not necessarily recapitulating the syntax of

their native language. This study did not explicitly address center-embedding of constituents within those of the same type, but as previously discussed, dependency length is likely a relevant factor in the processing of center-embedding versus branching. Our experiments set out to explicitly test learnability differences between dependency types.

However, it is unclear how crossed dependencies fit in with a dependency length minimization account. Like center-embedding, crossed dependencies create a longer total dependency length than right or left branching (Gómez-Rodríguez & Ferrer-i-Cancho 2017, Ferrer-i-Cancho 2006). The total dependency length is the same for comparable center-embedding and crossed dependencies (and both are longer than branching), as can be seen by inspecting Figure 4.1, so on these grounds there is no reason either should be favored.² Another possible factor may be computational complexity. Crossed dependencies are more complex than center-embedded dependencies on the Chomsky hierarchy, because they require context-sensitive rewrite rules in addition to those that do not rely on context, while center-embedded dependencies can be produced with a more restrictive set of rules (Hunter 2021: 78). While center-embedded dependencies can be produced by a context-free grammar, crossed dependencies require a more complex (mildly) context-sensitive grammar (Öttl et al. 2015, Partee et al. 1990: 505)³. Under the assumption that the dependency patterns that are more commonly found in human languages are the less computationally complex ones, the Chomsky hierarchy is consistent with natural language data in that center-embedded dependencies seem to be more common than crossed dependencies. As will be shown below, however, the Chomsky hierarchy does not appear to clearly map onto the real cognitive difficulty

² However, in a crossed-dependency pattern, the maximum length of individual dependencies is shorter than in center-embedding constructions. Therefore, if dependency length minimization is taken to set a limit on individual dependency lengths as well as total length, crossed dependencies would be favored over center-embedded. Thanks to an anonymous reviewer for this observation.

³ But see Pullum and Gazdar (1982) and Gazdar and Pullum (1985) for discussion of whether the presence of crossed dependencies really demonstrates that a natural language is not context-free, with consideration of some specific examples and arguments.

of the associated dependency structures (see also Chesi & Moro 2013), and the present experiments provide further evidence against a straightforward mapping.

4.1.2.2. Processing and learnability of dependency structures: Experimental evidence

4.1.2.2.1. Processing of natural language

Some experimental evidence (Bach et al. 1986) suggests that crossed dependencies are easier to process than center-embedded dependencies, which is surprising in light of the marginal status of the former compared to the latter in natural languages.

In a comprehension experiment, Bach et al. (1986) found that Dutch speakers could comprehend crossed dependencies more easily than German speakers could comprehend equivalent center-embedded dependencies in their native languages. The difficulty of comprehension between two-verb and three-verb sentences increased sharply for both dependency types, but more so for center-embedding than for crossed dependencies. Right-branching paraphrases were found to be easier than either. These findings held for both subjective impressions of comprehensibility and performance on a comprehension test. However, the authors consider that some non-syntactic features of Dutch and German may have influenced sentence processing, namely case marking (which was factored out of the stimuli but could still influence the strategies adopted by speakers) and the stress patterns on the verb clusters (Bach et al. 1986: 261). Therefore it is not certain how their results generalize beyond these languages, or whether comparing across languages in this way is even a valid comparison.

There are several possible explanations for the greater ease of crossed dependencies. For instance, crossed dependencies may be more tractable in speech than center-embedded dependencies because they make it easier to integrate useful structures in real time -- i.e. in a crossed sentence of the form *N1 N2 N3 V1 V2 V3* one can construct the meaning “N1... V1” as soon as the verb cluster begins. The equivalent is not possible with a center-embedded

structure (*N1 N2 N3 V3 V2 V1*), as it would be necessary to hear the whole before *V1* is available to match up with *N1*. While “*N3 V3*” is available when the verb cluster begins, the listener still must wait to determine how this information is incorporated into the greater structure of the sentence, rather than having the more global information supplied by *V1* (Bach et al. 1986: 260-1). While overall dependency length is comparable between equivalent crossed and center-embedded strings, the particular arrangement of dependencies may make processing easier for crossed -- because, as noted above in footnote 3, maximum dependency length is shorter than in a center-embedded phrase. The prevalence of center-embedding in natural languages, compared to crossed dependencies, is therefore hard to explain purely on the basis of differences in processing.

4.1.2.2.2. Sequence learning and artificial language learning

There is also evidence from nonlinguistic sequence learning and artificial grammar learning concerning the greater ease of crossed dependencies compared to center-embedded dependencies. However, how well these findings generalize to natural language is not clear.

Conway et al. (2003) confirmed that humans have more difficulty learning center-embedded patterns in meaningless visual or auditory sequences, compared to branching dependencies. In this experiment, the dependencies were matched pairs of letters. In another foundational experiment, Fitch & Hauser (2004) found that humans are easily capable of learning a center-embedded grammar of the form *AnBn*. However, while Fitch and Hauser (2004) analyzed the *AnBn* grammar as having center-embedded dependencies between *A* and *B* elements, this is not the only possible analysis: since any *A* element can form a dependency with any *B*, such strings can also be understood as crossed. In addition, the strings can be processed through count-and-match (*N A*'s, *N B*'s) with no need for dependencies between elements (Corballis 2007, Rogers & Pullum 2011). Perruchet & Rey (2005) attempted to replicate Fitch & Hauser's findings, but discovered that subjects did not succeed in learning the

pattern when required to recognize center-embedding explicitly. Therefore, it is not entirely clear whether humans can easily learn and process center-embedded nonlinguistic strings.

Further experiments (De Vries et al. 2008, Uddén et al. 2012) employed stimuli in which specific A and B elements formed dependency pairs. In the stimuli used by De Vries et al., dependencies consisted of specific pairs of nonsense syllables, such as “de... bo” or “gi... fo”; wherein A syllables had a front vowel and B syllables a back vowel. Their results showed that participants who learned the specific pairings could not easily distinguish hierarchical embedded sequences (of the form A1 A2 A3 B3 B2 B1) from superficially similar ones with the same elements ordered incorrectly (e.g. A1 A2 A3 B3 B1 B2). The results suggested that participants were attentive to surface features of the strings -- i.e. all As come before all Bs, and the number of As matches the number of Bs -- but not dependency order. Uddén et al. (2012) performed a similar experiment with visually presented sequences of letters that formed arbitrary dependency pairs (e.g. F...L or D...P), and found that crossed dependencies were more easily learnable than center-embedded patterns. Fitch & Friederici (2012), reviewing this line of research, also point out that a string of the form $A_n B_n$ can be analyzed several different ways (e.g. count-and-match, embedding, or crossed dependencies), and the ability to distinguish matched from mismatched sequences does not reveal which strategy is actually being used. Therefore, it is questionable whether recognizing or creating $A_n B_n$ strings requires a grammar with multiple dependencies, center-embedded or crossed. To test learnability or comprehensibility of dependency structures, it is necessary for the stimulus strings to have some clear indication of how elements link to form dependencies.

Other sequence-learning studies have explored differences in learnability between center-embedded and crossed dependencies, using strings where dependencies are indicated by some similarity between elements. Vogel et al. (1996) predicted that crossed dependencies should be easier to learn and process, as they are amenable to a count-and-match strategy, while recognizing that center-embedded patterns require the additional operation of reversing

half the string. However, experimental results do not clearly support this prediction. Öttl et al. (2015), for example, trained human participants on strings of nonsense syllables instantiating center-embedded or crossed dependencies. Syllables could fall into two categories depending on their vowel: A (vowel [e] or [i]) and B (vowel [o] or [u]). The dependencies were formed of syllables with the same initial and final consonant; e.g. “del” and “dol” or “tix” and “tux”. Strings could follow one of two grammars: center-embedded (A1 A2 A3 C B3 B2 B1) or crossed (A1 A2 A3 C B1 B2 B3). They found that there was no clear difference in learnability between grammar types. Again, this is unexpected given the typological distribution of these patterns, with crossed dependencies being much rarer than center-embedding. However, findings concerning nonlinguistic stimuli with dependencies indicated by phonological similarity may or may not generalize to artificial language stimuli with semantics. The present experiment addresses this issue with meaningful stimuli.

4.1.2.2.3. Our experiments

The stimuli in these previous studies of center-embedded and crossed dependencies were meaningless strings of sounds or syllables (i.e. not corresponding to any referent such as pictorial stimuli), in which cues to dependencies were absent or unclear. In the present study, we attempt to test for differences in learnability between dependency structures, and the role of learnability as a factor in language typology, using an artificial language task in which strings of novel words are associated consistently with visual stimuli which show the hierarchical relationship between elements described in the artificial language description. Previous studies suggest that participants may not readily perceive dependencies in nonlinguistic strings, but adding semantics in the form of associated visuals should make dependencies between elements clearer than they would be in either $AnBn$ strings, or strings in which dependencies are indicated by a perceptual similarity, e.g. alliterative syllables.

In our experiments participants learn an artificial language consisting of nested adpositional phrases. We used NPs and adpositional phrases rather than clauses because, per Hawkins (1994), center-embedding is more tolerated in NPs than clauses, and also because it is easier to clearly represent spatial relations (e.g. *the cat on the mat next to the table*) than transitive actions (e.g. *the cat chased the rat that ate the malt*) in a static image.

First, we assessed the learnability of crossed, center-embedded, and branching dependencies; while previous studies have addressed the processing cost of different dependency types (Bach et al. 1986) or the learnability of long-distance dependencies (Fedzechkina et al. 2018), none has systematically compared the learnability of all three dependency structures in the same paradigm, or used artificial languages, which would eliminate the confounds introduced by natural languages like Dutch and German. The second experiment used an iterated learning methodology to explore the development of consistent syntactic structures from initially random input; by iterating the language through multiple participants, individual learning biases are amplified and clarified. In both experiments, participant productions were analyzed to observe how well the input was replicated and how it was transformed through learning.

4.2. Experiment 1: Learnability

In this experiment, we set out to test the learnability of different dependency types in a small artificial language, in order to see which dependency orderings could be learned accurately and generalized to descriptions of items not seen in training. In addition, we compared participant-produced descriptions to different grammars to see how participants were interpreting or transforming the grammar – for example, by converting center-embedding into the apparently easier crossed grammar, or flipping head noun order.

4.2.1. Methodology

4.2.1.1. Participants

This study was conducted online; participants were Amazon Mechanical Turk workers who were compensated financially for their time (\$5 per task). The task was advertised through mTurk as an “Alien Language Game.” Only participants who met the following criteria could work on the task: US residents, minimum approval rate of 97%, and at least 1000 HITs completed. All were native English speakers according to self-report, though some spoke other languages. Participants were assigned randomly to one of six syntactic order conditions, as discussed below. In total, 140 participants were tested, 20 of whom were excluded because they took written notes (see below).

4.2.1.2. Stimuli

Stimuli were composed of images of four unfamiliar objects from the NOUN database (Horst 2015), arranged into scenes of 1-4 objects and labeled in an artificial language (Figure 4.3). This language consisted of two adpositions: *rae* “atop” and *moy* “to the (viewer’s) left of,” and four nouns, one for each object. Ten sets of four nouns were used, with each participant being allocated to a randomly-chosen set. Nouns were generated from a set of syllables of either CV or CVC structure, with four possible onset consonants (*t*, *v*, *s*, *k*), four vowels (*a*, *o*, *i*, *u*), and three possible endings (no consonant, *l*, *n*). Each noun had two syllables, such that both syllables had to share exactly two of the following: onset consonant, vowel, and final consonant (i.e. the syllables could not be fully identical). Within each set of four, each noun began with one of the onset consonants. This internal reduplication was used to make each noun more distinctive and easier to learn (cf. Ota & Skarabela 2016). In addition, each of the four nouns was required to have a mean Levenshtein distance of at least 5 from the others. Nouns matching English words (e.g. *sa/sa*, *tiki*) or which sounded like English words (e.g. *kuki* =

cookie) were excluded. This produced sets of four distinct, recognizable novel nouns (examples in 8).

8. Example noun lexica:

kilkul, vanva, tovo, sunsin
kuka, vinkin, tultol, solsil
kakan, volsol, tinkin, sulsal



	Head Initial	Head Final
Branching	<i>kilkul moy vanva rae tovo</i> A left.of B atop C	<i>tovo rae vanva moy kilkul</i> C atop B left.of A
Center-Embedded	<i>kilkul vanva tovo rae moy</i> A B C atop left.of	<i>moy rae tovo vanva kilkul</i> left.of atop C B A
Crossed	<i>kilkul vanva tovo moy rae</i> A B C left.of atop	<i>rae moy tovo vanva kilkul</i> atop left.of C B A

Figure 4.3: Sample scene with description in each of the six syntactic orders. Objects are labeled with letters for clarity here and in other example scenes; no such labels were used on stimuli for the actual experiment.

The syntax of the language could follow one of six combinations of NP order and adpositional phrase order (cf. Kuno 1974: 127-8): two branching grammars (an English-like grammar with noun initial NPs and prepositions, and the reversed grammar with noun final NP with postpositions), two crossed-dependency grammars (with noun-initial NPs and postpositions, or with noun-final NP and prepositions)⁴, and two center-embedding grammars

⁴ There are two other logically possible crossed grammars: noun-initial with prepositions (Adp1 Adp2 N1 N2 N3) and noun-final with postpositions (N3 N2 N1 Adp2 Adp1). In these orders, the head noun would be at the middle of the phrase rather than the periphery; we were concerned that this could have

(noun initial NPs with postpositions [N1 [N2 N3 Adp2] Adp1], noun final NPs with prepositions [Adp1 [Adp2 N3 N2] N1]). Examples are shown in Figure 4.3. Head order was manipulated to investigate whether unfamiliar syntactic order in general, as opposed to the dependency order per se, negatively affected performance. A pilot experiment (detailed in Appendix 2, section 1) using only center-embedded and branching grammars, and in which results were free-typed, yielded similar results to those of the presently discussed experiment.

4.2.1.3. Procedure

Before the task, participants were asked not to take written notes (“Please do not take notes during the task! We are interested in what your brain can do, not what your brain plus a notepad can do.”). At the end of the experiment, alongside other demographic questions, participants were asked whether they had taken written notes (“Did you write stuff down or take notes during the task? Please be honest - it won’t affect your payment, we promise, and if you tell us now we can correct for this in our analysis without affecting the validity of the experiment.”). Participants who indicated at this point that they had taken written notes were paid in full but their data was excluded from analysis. 20 participants were excluded.

The experiment was organized into three main phases: an initial vocabulary training phase, during which participants were trained to criterion on the vocabulary items (nouns and adpositions), a multi-word expression training phase, during which participants were trained on multi-word labels describing scenes featuring multiple objects, and then a final test phase, in which participants were tested on their ability to produce descriptions of the scenes.

Phase 1: Vocabulary Training

In the initial vocabulary training phase, participants were trained on the meanings of the four nouns for the four novel objects, and then the adpositions. Participants were given training trials in which an adposition or noun was presented passively, and comprehension trials in

introduced some additional confounds, e.g. by making the head noun less salient, so these orders were not included.

which participants were prompted with an adposition or noun and required to select the matching image. Example noun training and comprehension trials are shown in Figure 4.4; example adposition training and comprehension trials are shown in Figure 4.5.



Figure 4.4: Noun training (a), comprehension (b), and feedback on comprehension (c)

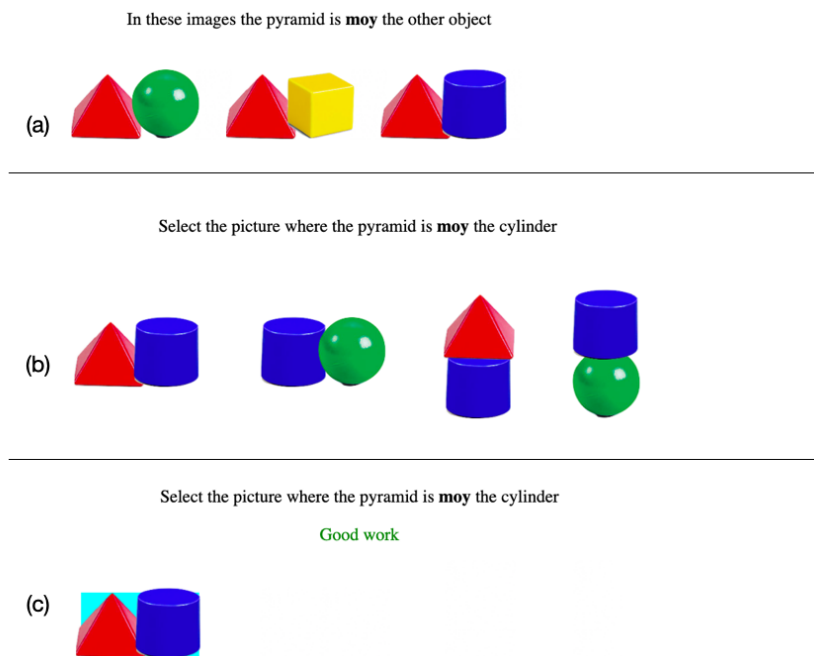


Figure 4.5: Adposition training (a), comprehension (b), and feedback on comprehension (c)

In order to ensure that the meaning of the artificial adpositions was clearly indicated, the adposition was used in an English descriptive sentence accompanying several example scenes; pilot experiments showed that adposition meaning was not always easily inferred from complex scenes and their associated artificial language descriptions (see Appendix 3). Training trials were self-paced; participants advanced to the next trial by button press.

Comprehension trials were structured as follows: the participant was shown the four novel objects (in the case of noun trials) or four spatial configurations of English-named objects (in the case of adposition trials) and asked to select the object or spatial configuration corresponding to a noun or adposition, respectively. After making a selection, participants were shown feedback indicating the correct selection. If they had selected correctly, the text “Good work” appeared; if they were incorrect, the text “Sorry, incorrect” appeared. In either case, all scenes except the correct one (corresponding to the description) disappeared.

In the noun training phase, participants received four noun training trials (one per object), followed by four noun comprehension trials, and were trained to criterion (i.e. the training-comprehension sequence was repeated until all were answered correctly). Adposition training followed the same structure.

Phase 2: Multi-word description training

In the second phase of the experiment, participants were trained on multi-word descriptions for scenes involving either two or three objects. This phase progressed in difficulty: participants were given eight training and eight comprehension trials on scenes featuring two objects, then eight training and eight comprehension trials on scenes featuring three objects. As in the vocabulary training phase, participants received both passive training trials and comprehension trials (see Figure 4.6 for sample training and comprehension trials for a two-object scene); unlike in the vocabulary training phase, progression did not depend on performance on comprehension trials.

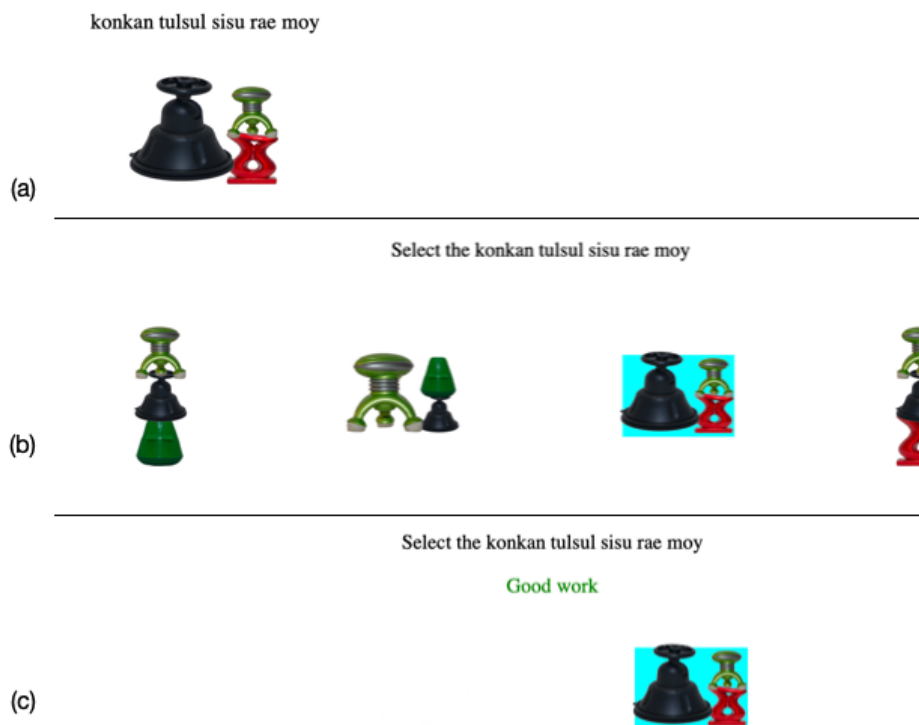


Figure 4.6: Phrase training (a), comprehension (b), and feedback on comprehension (c).

Training trials followed the same structure as in the one-word phase. After training trials were completed for one phase, participants would be prompted to move onto comprehension trials.

In comprehension trials for multi-word descriptions, participants were given a description in the target language and asked to select the appropriate object or configuration of objects from four possibilities with the same number of objects as the target. This set contained the target and three distractors:

1. The same objects as the target image, but in a different configuration.
2. Different objects from the target scene, but in the same configuration as the target.
3. Different objects in a different configuration: the objects from distractor 2 in the configuration from distractor 1.

The four options (target plus three foils) appeared in random order (Figure 4.6b). Feedback on correct and incorrect responses was the same as for noun and adposition training.

Phase 3: Production test

Finally, participants moved on to a production test (Figure 4.7) in which they produced descriptions for scenes. Again, these trials progressed in difficulty, with four levels (one-object through four-object scenes). For levels 2 and 3, participants saw the eight scenes that they had been trained on, and four novel scenes; level 4 consisted of 12 novel four-item scenes. On each trial, participants were presented with an image of a scene and provided with a set of six buttons⁵ corresponding to their randomly selected lexicon: four two-syllable nouns plus *moy* and *rae*. Pressing each button entered its word into the text box, and participant entries were required to exactly match a required length: $2n - 1$ for n objects, e.g. five words for an a scene of three objects. Once the required number of words was entered, the participant automatically progressed to the next trial.



Figure 4.7: Production trial at level 3: participants see a scene, and generate a description by clicking vocabulary buttons. A partially built description is shown.

Post-experiment demographics and debriefing

Following the production task, participants were given a brief survey in which they were asked to indicate their native language, list other languages they spoke, and provide any additional comments they had on the task. We also assessed whether they understood the

⁵ In the pilot experiment (see Appendix 1), responses were collected using a free text entry box; results were overall similar to the present experiment.

meaning of the artificial adpositions. For each adposition, participants were given a multiple choice question from which they were required to select one of the following meanings: “To (your) left of”; “To (your) right of”; “Horizontal (either left or right)”; “Atop”; “Under”, “Vertical (either atop or under)”; “Don’t know”; and “Other” (with a free text entry box).

4.2.1.4. Analysis: Calculating accuracy for test trials and best-fit grammar

Comprehension performance (i.e. whether participants selected the correct referent at each comprehension trial during training) was analyzed with a logit mixed effects model, to give a measure of learning accuracy during training. Level was coded with successive differences contrast coding.

Accuracy for the final set of production test trials was measured by calculating the normalized optimal string alignment (optimal string alignment divided by length of the longer string, calculated with the R *stringdist* package, Van der Loo 2014) against the correct description in the language the participant was trained on, and subtracting the resulting normalized distance from 1 to get an accuracy score (an accuracy score of 0 indicates no correspondence between the participant-produced description and the trained label; an accuracy score of 1 indicates perfect correspondence). However, using raw string edit distance on the produced labels would result in a non-uniform penalty for errors: nouns are longer than adpositions, therefore noun errors would be penalized more heavily. Furthermore, nouns vary in length, and thus not all noun errors would be weighted equally. We therefore replaced each word in each string to be compared with its initial letter prior to calculating string edit distance (e.g. *rae vuntun vuntun* > *rvv*), ensuring that all errors were weighted equally. The resulting correctness score for each participant-produced description was used in a mixed effects model to analyze production test performance.

In order to assess how well grammatical features were preserved in different conditions (and generalized to new stimuli), and how grammars were modified through learning, we

estimated which of many possible grammars was most likely to underlie each string in each participant's productions. We considered a set of 64 possible grammars. Grammars varied in their dependency type and word order, and in the semantics associated with the adpositions. Grammars could have the following orders: branching, center-embedded, or crossed dependencies. Branching and center-embedded grammars could be noun-final or noun-initial, and crossed dependencies could have four total combinations of noun positions (initial or final), and pre- or postpositions. This gives eight possible word orders (including two crossed orders not represented in the stimulus conditions: noun-initial with prepositions and noun-final with postpositions; see footnote 2 in section 2.1.2). In addition, there were four possible combinations of correct and reversed interpretations for the adpositions *rae* and *moy*: 'atop'/'below' and 'left of'/'right of' respectively, and the possibility that the vertical and horizontal adpositions could be switched in meaning (e.g. *rae* = 'left of', *moy* = 'atop').⁶ This produced eight possible adposition interpretations.

For each scene seen by a participant, the corresponding string in each of the 64 grammars was generated, using the initials of the object labels that participant had seen. These strings were then compared to the participant-produced description, using optimal string alignment and normalisation as described above, to allow us to measure how well the string from each of those 64 grammars matched the participant's production for that scene. Possible grammars were further narrowed down using the participant's stated interpretation of adpositions from the post-task survey. For example, if a participant indicated that *moy* meant "atop", all grammars featuring another meaning for that adposition were eliminated from consideration. Only directionally-specific glosses allowed candidate grammars to be removed; unspecified (e.g. the "either left or right" answer) or uninterpretable ones (e.g. a filled-in answer

⁶ Grammars with directionally unspecified adposition glosses ("next to" for horizontal or "vertically adjacent to" for vertical) were not included because they would be inherently indeterminate as to head order. If these grammars were allowed, all strings matching a grammar with a specific adposition interpretation would also match the nonspecific one, causing nonspecific grammars to win out over specific ones.

that did not correspond to any identifiable meaning) did not eliminate any grammars. In many cases, multiple grammars were applicable to the same string. For example, a noun-initial grammar with the trained adposition meanings (*moy* = left of, *rae* = atop) would produce identical strings to a noun-final grammar with the opposite adposition meanings (*moy* = right, *rae* = under), as shown in Figure 4.8. It was not always possible to eliminate one of these competing grammars if participants had not specified their adposition interpretations sufficiently.

Another ambiguity involved strings of the form *N1 N2 N3 Adp1 Adp2*, which could be interpreted as either a crossed or a center-embedded grammar, if the string of adpositions was palindromic or all were identical. Indeterminacy between crossed and center-embedded could also occur in three-word descriptions of the form *N1 N2 Adp*, if the adposition directionality was not specified. These were labeled as their own category (“center-embedded/crossed”).

4.2.2. Results

4.2.1.1. Comprehension

We analyzed comprehension testing accuracy for scenes of two and three objects (Figure 4.8).

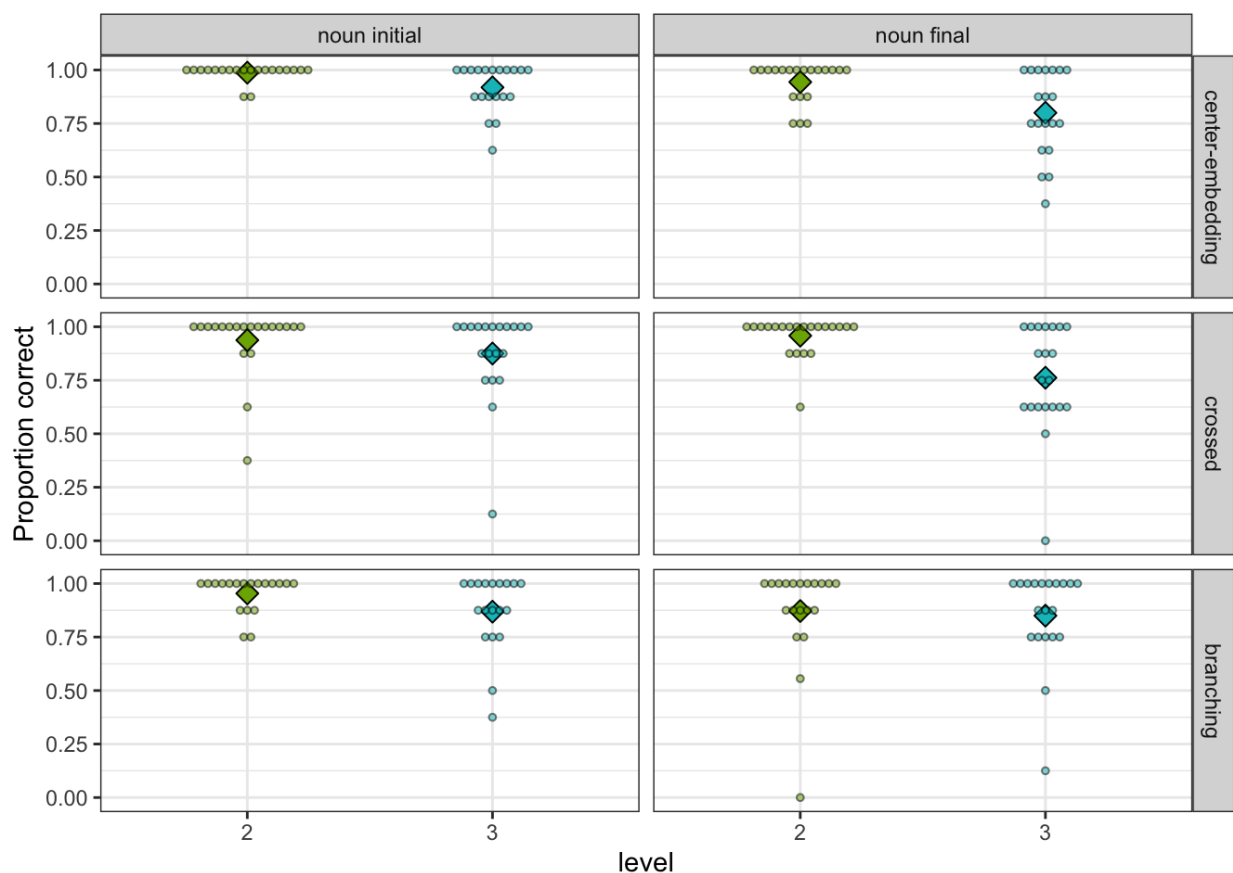


Figure 4.8: Performance on comprehension task, by condition and level (two and three objects). Each point represents one participant's performance at that level. Total $n = 20$ per cell. Large diamonds represent mean performance across all participants.

The single-object and adposition levels, which were trained to criterion, are excluded. Comprehension performance was analyzed with a logit mixed effects model with three fixed effects: dependency type (branching, crossed, center-embedding), head noun position (initial, final) and level (two objects or three). Dependency type was coded with Helmert contrasts, yielding a model with two dependency type contrasts, comparing crossed to center-embedding and then branching to the mean of crossed and center-embedding⁷. Head position and level were sum coded. The model included by-participant random intercepts and by-participant random slopes for level.

⁷ In this model, correction for multiple comparisons is not required, as only two values are compared at each contrast: crossed versus center-embedded, and the mean of the previous two conditions versus branching.

Performance in comprehension trials was generally very high; the mean comprehension for crossed and center-embedded conditions was marginally lower than for branching ($B = -0.25$, $SE = 0.32$, $p = .14$). Comprehension accuracy was marginally lower in the noun-final condition than the noun-initial condition ($B = -0.43$, $SE = 0.25$, $p = .088$), and was significantly lower at the three-item level than the two-item level ($B = -1.7$, $SE = 0.38$, $p < .001$). In addition, a significant interaction occurred between dependency type and level, where performance declined more between levels in the crossed and center-embedded conditions than in the branching conditions ($B = 0.33$, $SE = 0.17$, $p = .049$). There were no significant interactions between level, dependency type and initial or final order.

4.2.2.2. Production accuracy

Figure 4.9 shows participant accuracy in the final-phase production task, across all levels. In the first analysis, covering all data, dependency type (Helmert coded), head noun order (sum coded), and level (successive differences) were fixed effects. As expected, branching grammars were the easiest to learn: the mean learning accuracy on center-embedded and crossed dependencies was significantly lower than for branching structures ($B = -0.02$, $SE = 0.001$, $p = .04$). Within the two harder dependency types, learning accuracy for crossed grammars was not significantly different from center-embedding grammars ($B = -0.01$, $SE = 0.02$, $p = .52$). There was also a significantly greater decline with level in noun-final than in noun-initial conditions ($B = -0.03$, $SE = 0.01$, $p < .001$). The effect of noun order was not significant; there were no other significant main effects or interactions.⁸

In summary, production performance on branching grammars was significantly better overall than for the other two types, which did not differ significantly from each other. The interaction of noun order with level (number of objects) was also significant: i.e. performance

⁸ For all scenes that were seen in training, there were no significant effects of dependency type or head order except that performance on head-final orders was significantly lower ($B = -0.03$, $SE = .01$, $p = .01$, all other $p > .1$), nor interactions between syntax type and other variables. For novel items, there was no significant main effect of dependency ($p > .5$ for both comparisons); however, performance was again significantly lower in head final ($B = -0.07$, $SE = 0.02$, $p < .001$)

declined with level more sharply in the noun-final condition, although noun order did not produce a main effect.

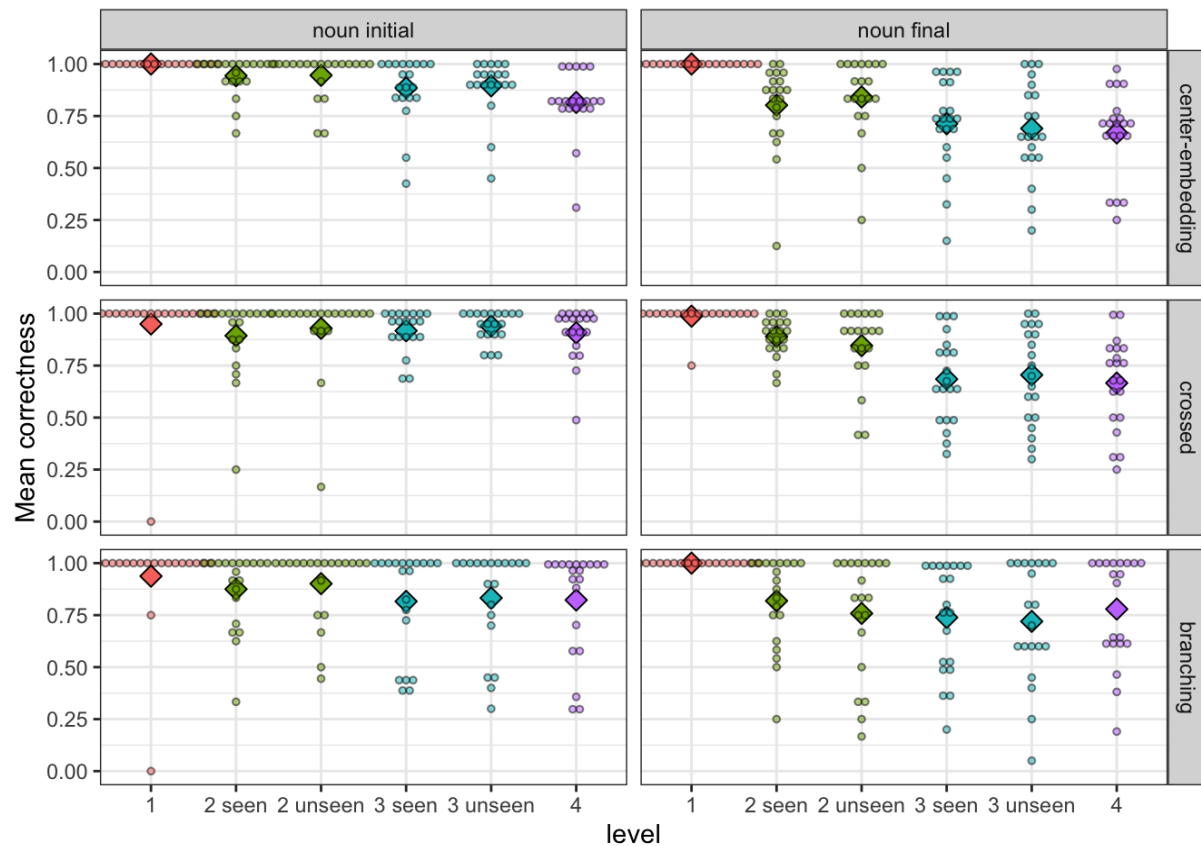


Figure 4.9: Production correctness (1 minus normalized edit distance from correct) by level and condition. Each point represents one participant's performance at that level; large diamonds represent mean performance across all participants.

To assess how well the grammar was being generalized to new items, for levels in which both familiar and novel scenes appeared in the production task (two and three items), accuracy was compared across previously seen and unseen stimuli. This model had the same fixed effects as the previous, plus seen vs. unseen. There was no significant difference in accuracy between the 8 scenes seen in training and the 4 novel ones at each level ($B = 0$, $SE = 0.005$, $p = .976$); there was, however, an interaction between seen/unseen and noun order. Specifically, the difference between seen and unseen was more pronounced in the noun-final condition, with lower performance on unseen test items ($B = -0.01$, $SE = 0.01$, $p = .03$). This shows that in the noun-final conditions, participants found it harder to generalize the learned language to items

not seen in training, whereas dependency type did not appear to make a difference. There were no other significant main effects or interactions. We also analyzed performance on 4-object scenes alone to determine if there were any differences in generalization across conditions. There was no significant difference between branching and other dependency types ($B = -0.01$, $SE = .013$, $p = .2$), or between crossed and center-embedded ($B = -.007$, $SE = .023$, $p = .75$), but performance was significantly lower in the noun-final conditions ($B = -.07$, $SE = .023$, $p < .0001$). Overall, as described above, performance was best on the branching dependency type, but participants in this condition did not perform significantly better than those in the other conditions at generalizing to unseen stimuli, including scenes with four objects.

4.2.2.3. Grammars of participant productions

Figure 4.10 shows the best match grammar for each string produced by participants, organized by condition. Branching syntax was well-replicated, with most participants who were trained on a branching grammar producing descriptions which were consistent with a branching grammar (although not necessarily preserving order). For many participants, noun order was indeterminate because their adpositions were underspecified (see section 2.1.4), but noun-initial order was better preserved than noun-final. Participants trained on center-embedded syntax did not replicate this pattern well, instead often producing strings best matched by a crossed grammar (dark green) or indeterminate grammar (light green). Conversely, crossed grammars were better preserved than center-embedding grammars, and were not reanalyzed as center-embedding (as can be seen in the rarity of strings matching this grammar, coded as pink cells, in the figure). Note also that generalization takes place: when a grammar is inferred for the “seen” items, it is in most cases carried over to the “new” items where an entirely new label must be composed.

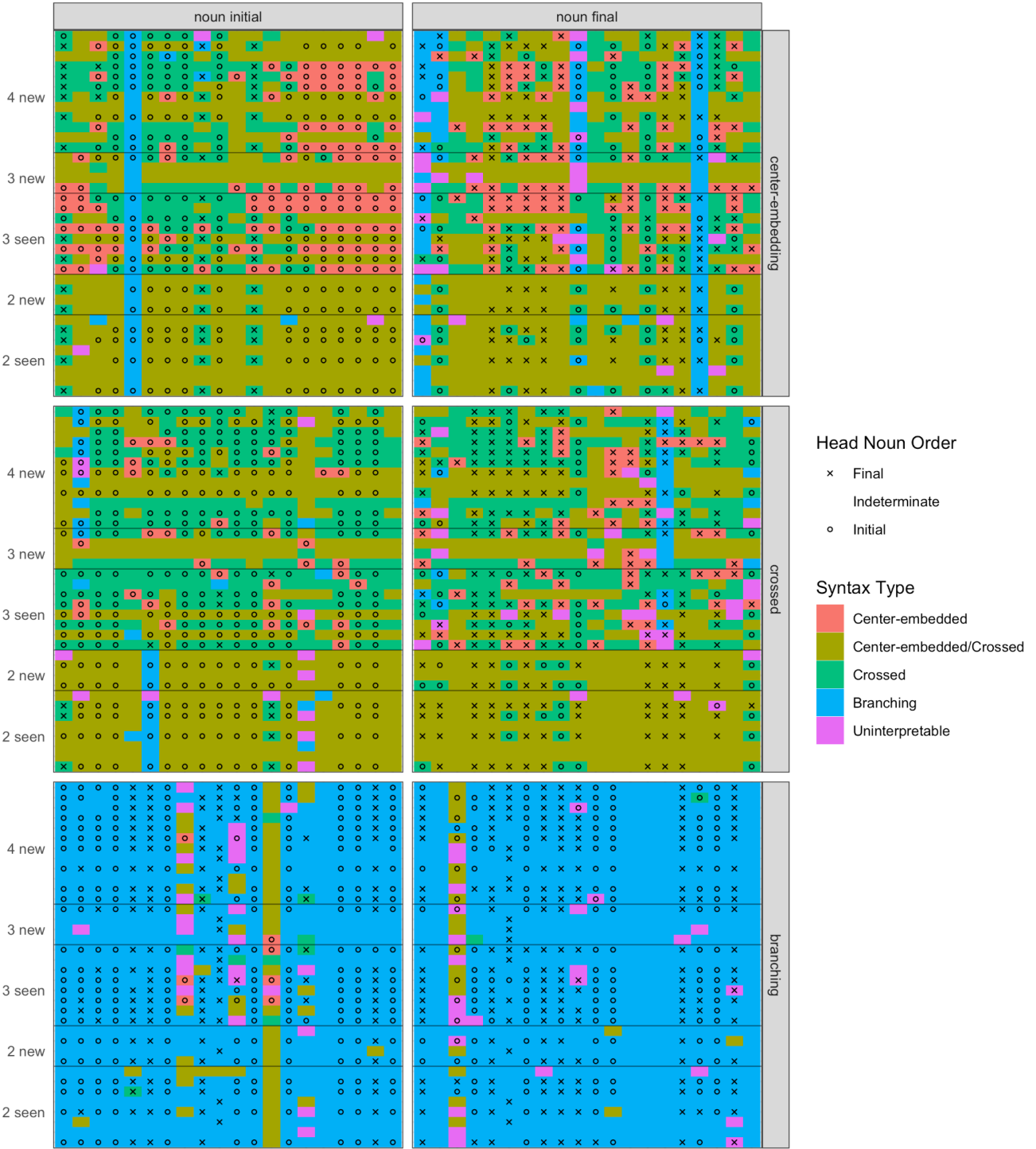


Figure 4.10: Participant production grammar by string and condition, Experiment 1. Each column within a facet (condition) corresponds to a participant's productions, with each cell being one string. Color represents dependency type, and X/O symbols represent head order, as listed in the legend. The sidebars indicate the number of objects in a scene and whether it was seen in training, or new to the production task.

4.2.3. Discussion

These results, particularly the lack of a significant difference between accuracy for center-embedded and crossed grammars, and the occasional appearance of a crossed grammar as a best fit in the center-embedded condition (while the converse never happened), are consistent with earlier findings (Bach et al. 1986) that crossed grammars are not more difficult to learn than center-embedding grammars. This is a surprising finding under the assumption that typology and learnability should be aligned; as discussed above (in section 1), crossed dependencies are quite rare in natural languages, whereas the harder center-embedded dependencies are more common. No participants reported speaking Dutch, Swiss German, or Tagalog (which allow crossed dependencies), so natural-language influence was unlikely to have been a factor. On the other hand, as evident in the production tests, the difficulties caused by center-embedding (relative to other grammars) seem less pronounced than those caused by an order where nouns follow adpositional phrases, which would be unfamiliar to and difficult for native English speakers.

It is possible that grammars resembling crossed or center-embedded syntax have arisen from the constraints of the task: participants may have been filling in the names of objects, then adding adpositions to fill out the length of the full required phrase (as was necessary to advance to the next item). This would have yielded either (what looks like) a noun-initial center-embedded grammar (N1 N2 N3 P2 P1), a noun-initial crossed grammar with postpositions (N1 N2 N3 P1 P2), or a noun-final crossed grammar with postpositions (N3 N2 N1 P2 P1), which did occur for some items in some participants' productions. This "reading off" strategy would favor crossed grammar more than center-embedding: the strategy here would be to list objects, then list spatial relations, in the same order (or spatial relations, then objects). To replicate a center-embedded syntax with this strategy, either the list of objects or the list of spatial relations would have to be reversed. The asymmetry between crossed and center-embedded grammars – center-embedded becomes crossed but not vice-versa – would

be consistent with participants using this listing-off strategy, as well as being consistent with a preference for crossed dependencies over center-embedding.

Some uncertainty in the results was introduced by unclear adposition reporting. While the horizontal adposition *moy* was specifically defined as “right of”, or “left of,” for these meanings, the English *next to* was readily available and unspecified results were common. There is no equivalent unspecified vertical term (a few participants did gloss the “atop” adposition *rae* as unspecified vertical). Therefore, it was not always possible to disambiguate between two grammars. In the following experiment, we attempted to clarify how participants understood the meaning of adpositions by refining the final survey, which was also necessary to produce iterable results for the next generation in the chain.

4.3. Experiment 2: Iterated learning and the emergence of consistent branching direction

This experiment set out to examine the emergence and stabilization of a consistent grammar in nested locative phrases, using the same type of stimuli as in the previous learnability experiment, and furthermore to observe whether the results reflected natural language typology. We hypothesized that branching syntax would be predominant in the results, due to its greater learnability, whereas center-embedding and crossed grammar would be rare, in keeping with previous experimental results.

4.3.1. Background: Iterated learning and artificial languages

Iterated learning is a process in which participants are asked to perform a cognitive task, such as viewing and then repeating a sequence, and the response of one participant becomes the stimulus for the next. Each participant’s response to the input that he or she is exposed to is referred to as a *generation*, and the “genealogy” of all participant responses in the same line of descent constitutes a *chain*. The first participant is trained on experimenter-designed stimuli, henceforth referred to as *generation 0*.

Through the process of transmission in iterated learning, the initial stimulus is modified due to learners' cognitive and memory biases (along with whatever constraints are imposed by the task itself), which are amplified with each subsequent generation. If the stimulus for the first participant (generation 0) is initially random and structureless, it tends to develop structure through repeated transmission, and irregularities are smoothed out. Artificial languages which initially lack consistent structure develop compositionality and regularity through transmission (Kirby et al. 2008, Beckner et al. 2017, Kirby et al. 2014, Saldana et al. 2019). Artificial language learning experiments (e.g. Hudson Kam & Newport 2005, Fedzechina et al. 2018) confirm that learners regularize unpredictable input (but see Perfors 2016 for a counterexample). In addition, iterated learning can drive the regularization of features such as mapping of words to meanings (Real et al. 2009) and marking of plurals (Smith & Wonnacott 2010), increasing regularity by generation.

While we are not aware of any experimental studies looking at iterated learning and dependency ordering, there is at least one computational simulation of a similar process, using artificial neural networks to model language learning (Real & Christensen, 2009). In their simulation, networks were first pretrained on sequential learning, and then on a simple language based on phrase structure grammars. At the initial "generation," phrase structure rules were flexible, such that phrasal heads and dependents could occur in either order (e.g. possessive before NP or vice-versa). Once trained, networks were tested on different grammars, and the best-learned grammars were passed on to the next generation of networks, for hundreds of generations. Over time, the prevalence of consistent phrase structure rules with consistent head order across rules increased. As previously discussed, a combination of head-initial and head-final orders (e.g. head-initial noun phrases plus postpositions) can produce syntactic center-embedding. Therefore, consistent head order across phrase types produces a consistent branching grammar and decreases or rules out center-embedding. We find comparable results appear with human participants in a few generations.

4.3.2. Methodology

4.3.2.1. Participants

As in Experiment 1, participants were recruited online through Mechanical Turk and compensated \$5 for their time. In total, 192 participants were run, but all but 60 were excluded due to taking written notes, not providing a diverse enough set of labels, and/or not providing clear enough adposition responses (see Procedure below). Data from these 60 participants were analyzed, forming 12 chains of 5 generations each.⁹

4.3.2.2. Stimuli

Visual stimuli were the same as in Experiment 1. Each chain was assigned a randomly chosen set of 4 nouns from the 10 sets. At generation 0, the language used for scene labels was randomly generated; at each subsequent generation, the previous participant's labels from the production task were used for training, along with given adposition meanings.

Random stimuli for generation 0 were produced by listing the nouns and adpositions for the objects and spatial relations in each scene, and then scrambling the word order. Therefore, each description contained words representing the correct objects and spatial relations, but with no consistent syntactic order. For example, a scene with object B atop object A could bear the description (in English) "A B atop," "atop B A," "B atop A" and so on.

4.3.2.3. Procedure

The overall task followed the same structure as that in Experiment 1. At generation 0, four possible combinations of adposition meanings were used for training (left/atop, left/under, right/atop, right/under), with each being used in three chains (this was done to avoid possible confounds from learnability of different adposition meanings).

To clarify the adposition meaning that participants had arrived at, and to determine which meanings should be used to train the next generation, a visual component was added to the

⁹ A pilot experiment with a small number of 10-generation chains demonstrated that 5 generations were sufficient for the artificial grammar to stabilize on a consistent syntax.

final survey, asking participants to identify images corresponding to the meaning of each adposition (see Figure 4.11). A participant's adposition meaning was judged as consistent if the following criteria were met: a specific answer (e.g. *left* or *right* as opposed to *horizontal*) was given on the survey question on adposition meaning, and all and only the three images corresponding to that meaning were selected in the visual survey (a column in both of the scenes of images in Figure 4.11, as highlighted). Since adposition meaning was iterated along with labels, it was necessary to have fully consistent adposition meanings to create training trials at the next generation, and prevent adpositions from becoming underspecified (as they frequently were in preliminary pilot experiments as well as experiment 1); a participant's data was therefore only used for iteration if they produced consistent adposition meanings. Many participants did not fulfill this criterion. Participants were run until all chains were filled to the required five generations.

Please select all images (at least one in each row) in which the red pyramid is
"moy" the other object:

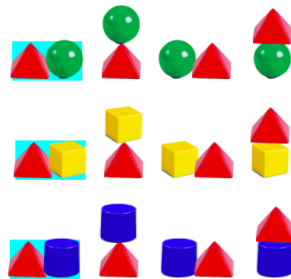


Figure 4.11: Visual adposition selection question (blue highlighting indicates selection)

At the production phase, as in Experiment 1, each participant saw and was asked to label forty total scenes: 20 that were seen in training with descriptions and 20 that were novel. In the training phase, Participant 1 learned a randomly generated Generation 0 language, which consisted of labels for 20 scenes. In the subsequent production phase, Participant 1 then produced the labels for these 20 familiar scenes, and was also asked to produce labels for 20 novel scenes. These 40 labels constituted the Generation 1 language. The labels for the 20 familiar scenes that Participant 1 produced in the production phase were used as in the input in

Participant 2's training phase. In Participant 2's production phase, the task was the same as for Participant 1: provide labels for the 20 familiar scenes from the training phase, and also for the same 20 novel scenes that had been shown to Participant 1. The same process was repeated for subsequent participants. Figure 4.12 summarizes the process.

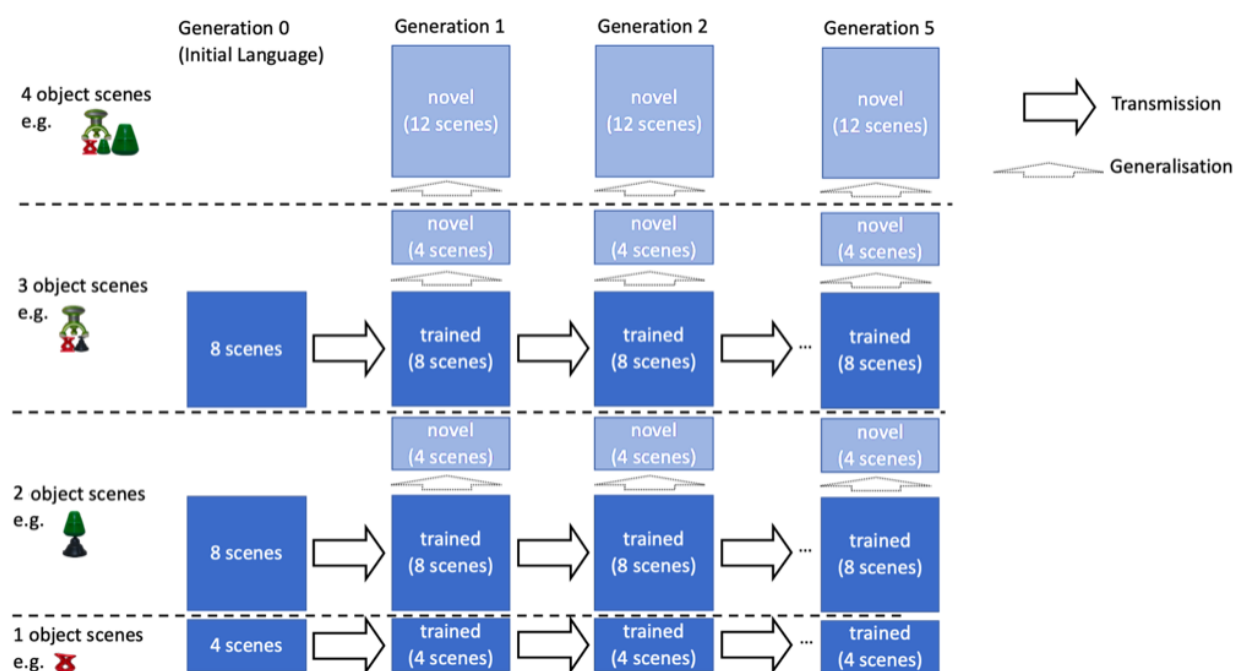


Figure 4.12: schematic of iteration in Experiment 2. Each participant saw and was asked to label forty total scenes. Participant 1 learned a randomly generated Generation 0 language, which consisted of labels for 20 scenes. In the subsequent production phase, Participant 1 was asked to label those scenes plus 20 novel ones. These 40 labels constituted the Generation 1 language. The labels for the 20 familiar scenes that Participant 1 produced in the production phase were used as in the input in Participant 2's training phase, and so on.

In order to be iterated to the next generation, participant output also had to adhere to criteria of minimum diversity (defined below). This was necessary to prevent the language from becoming degenerate and underspecified, i.e. using the same word to refer to multiple different objects, or only one adposition for both spatial relations (cf. Kirby et al., 2008; Beckner 2017). Criteria for diversity were as follows: Iterative productions required four different labels for the four objects, and at least eight different labels for the twelve scenes (multi-object) at each subsequent level (which included eight seen in training and four new for two-and-three-object

scenes, and twelve new scenes with four objects). This would allow enough unique labels for each of the eight scenes per level seen in training at the next generation. Since all participants provided unique labels for at least the eight seen-in-training items during the production task, the items did not have to be reordered to create a set of eight unique labels; consequently, all participants saw the same eight items in training at each level in each generation. A pilot experiment, detailed in Appendix 1, did not use adposition training but produced generally similar results to the present experiment with regard to dependency type.

4.3.2.4. Analysis

The same analyses were performed as for Experiment 1 on comprehension and production, but without condition, and including generation as a numeric. Grammars at each generation were analyzed for best fit with possible grammars in the same way as Experiment 1. For each generation of each chain, the entropy of the grammar distribution – the list of all possible grammars for all strings in a generation – was also measured and analyzed with a linear regression model using generation as a fixed effect and chain as a random effect. This provided a quantitative analysis of how the grammar was regularizing and becoming consistent in terms of dependency type.

4.3.3. Results

4.3.3.1. Comprehension

Comprehension performance was analyzed using a mixed effects binomial model with level (coded by successive differences contrast) and generation (coded numeric) as fixed effects, and generation/level slope by chain and participant as random effects. Comprehension scores were well above chance (25%) from the start and did not change with generation ($B = -.092$, $SE = .107$, $p = .392$). Comprehension scores for 3-object scenes were significantly lower than for 2-object scenes ($B = -0.747$, $SE = 0.359$, $p = .037$). There was no significant interaction between level and generation ($p = .96$).

4.3.3.2. Production: accuracy and consistency

Unlike comprehension, the production task showed significant generational changes (Figure 4.13). Descriptions for seen and unseen scenes were analyzed separately here. Production accuracy (i.e. accurately reproducing the training label, which is the label produced at the previous generation) for descriptions seen in training improved with generation ($B = 0.03$, $SE = 0.02$, $p = .045$). As evident in Figure 4.16, performance for 1-object items was at or near ceiling for most generations and chains. Performance on 2-object items was significantly lower than on 1-object items ($B = -0.32$, $SE = 0.06$, $p < .001$), and in turn, performance on 3-object items lower than for 2-object items ($B = -0.11$, $SE = 0.05$, $p = .03$). No generation-level interaction was observed.

Production accuracy for unseen items also improved with generation ($B = 0.12$, $SE = 0.01$, $p < .001$). There were no significant effects of level (number of objects per scene), and no interactions (all $p > .29$). Since participants had no access to any labels for unseen items created by previous-generation participants, the production of accurate labels is a clear sign of the grammar stabilizing on a generalizable structure, allowing participants at successive generations to produce similar labels even if the later participant did not actually see the label produced by the participant at the earlier generation. Even though comprehension scores did not increase significantly with generation, an improvement in production accuracy and consistency suggests that the languages were becoming more learnable, and more readily generalized to new scenes.

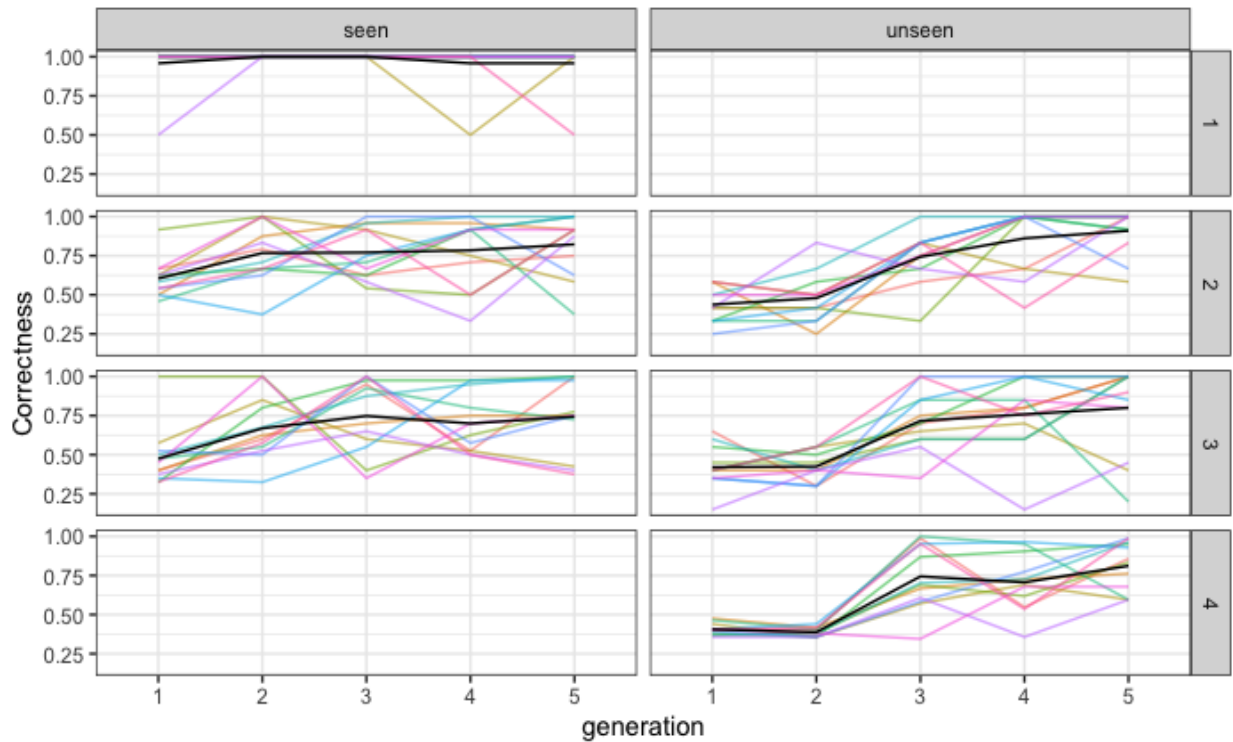


Figure 4.13: Production accuracy for seen descriptions, and consistency of descriptions for novel scenes. Facets 1-4 indicate the number of objects, colored lines are chains, the black lines represent the mean across all chains.

4.3.3. Grammar of participant productions

Analysis of the best-fit grammars for participant productions shows that a branching, English-like grammar in most chains as irregularities and variations are smoothed out.

Figure 4.14 shows the best fit grammar for each string, organized by chain, with each column showing a generation. There is a clear takeover of branching dependency structure, usually noun-initial, in most chains. Entropy of the grammar distribution decreased significantly over generations ($B = -0.21$, $SE = 0.03$, $p < .001$; Figure 4.15), consistent with an increase in uniformity.

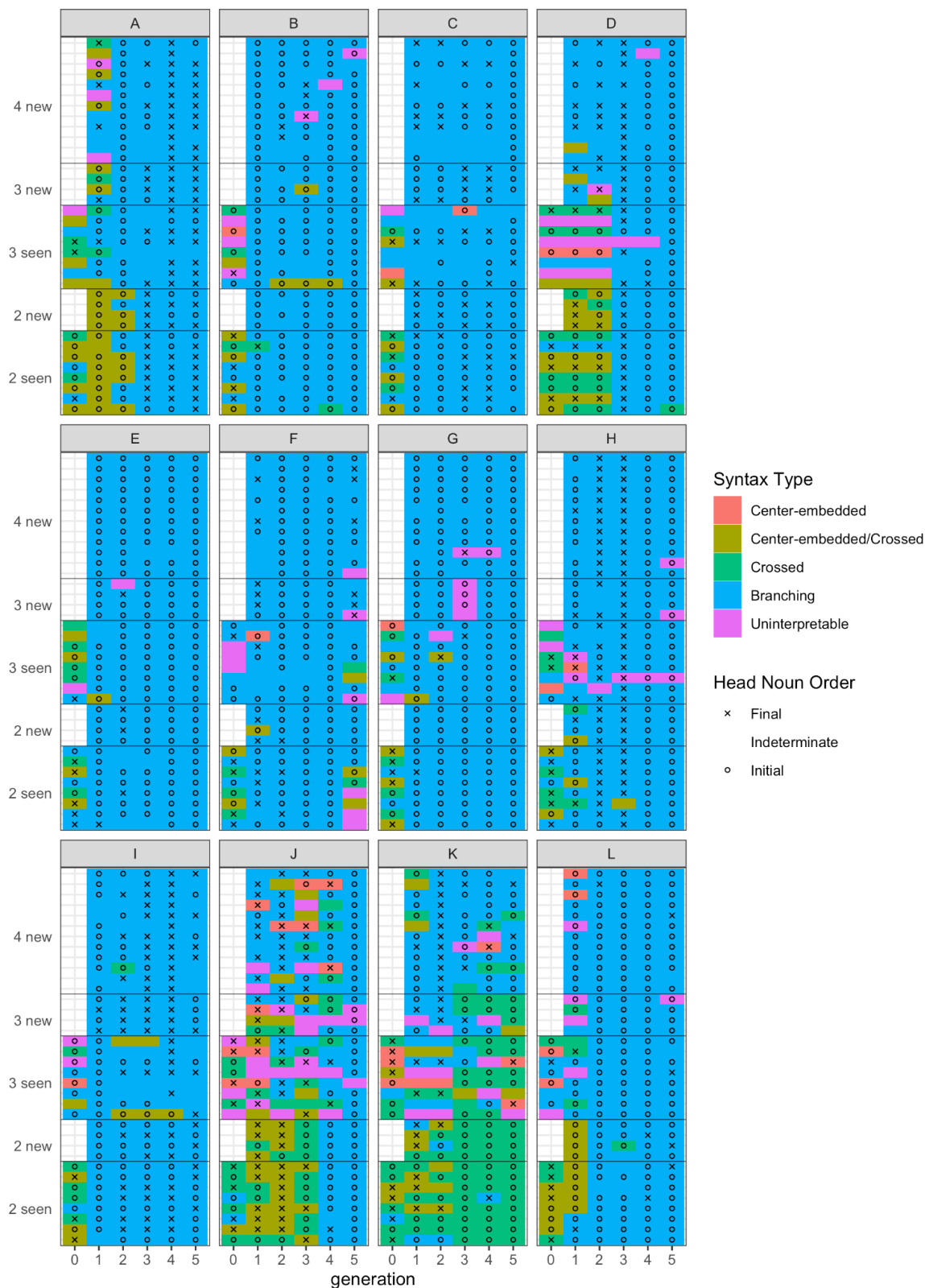


Figure 4.14: grammar by string, chain, and generation, Experiment 2. Each facet is one chain; generations (participants) are columns. Color represents dependency type and O/X symbols represent head order, as listed in the legend.

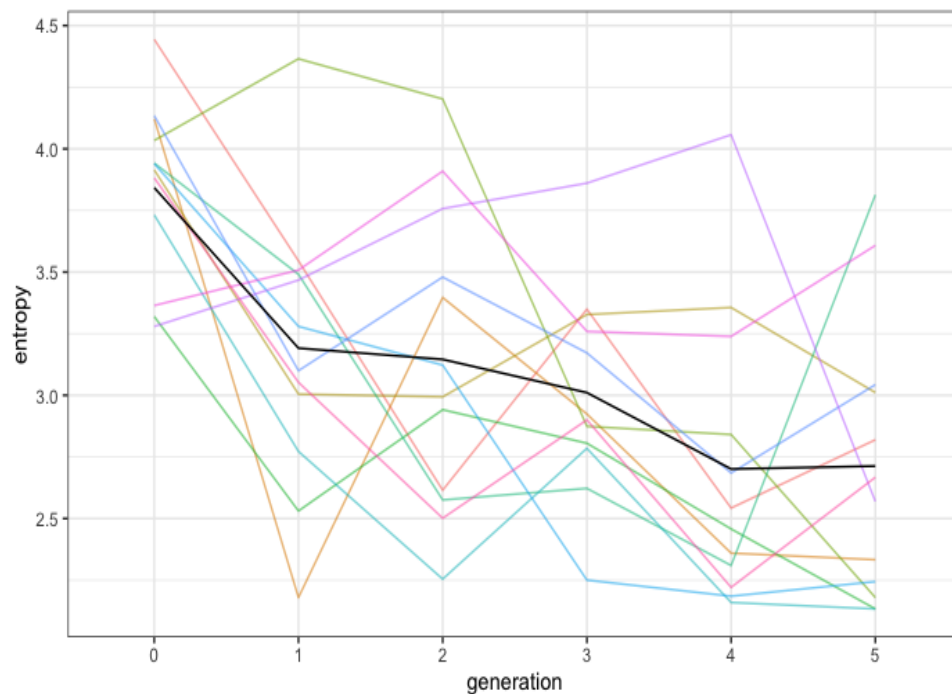


Figure 4.15: entropy of grammar distribution by generation and chain. Colored lines are chains; black line is the mean of all chains.

4.3.4. Discussion

The results of this experiment confirm the emergence of branching syntax as preferred over either center-embedded or crossed; branching emerged readily and usually stabilized once established. Examining Generation 5 languages shows predominant English-like syntax (branching, noun initial). Chain E, some items from which are shown in Figure 4.16, was typical in this respect.

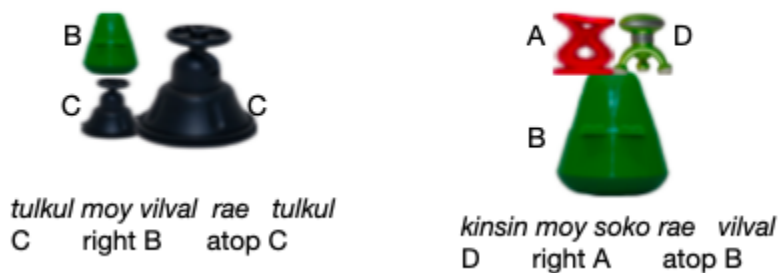


Figure 4.16: Items and labels from Generation 5, Chain E.

The chain designated A was typical in syntax type, but unusual in that a noun-final grammar predominated in the last three generations. This switchover coincides with, and may have been caused by, a change in the interpretation of the horizontal adposition: from left to right (see section 2.1.4 for how adposition meaning can determine the best fit grammar). One chain, K, was clearly anomalous, developing a crossed grammar for two-item pairs. Figure 4.17 shows some examples of pairs where the spatial adposition preceded the two object names. The given adposition glosses confirm a crossed grammar where the adposition comes before the head noun of the whole phrase.

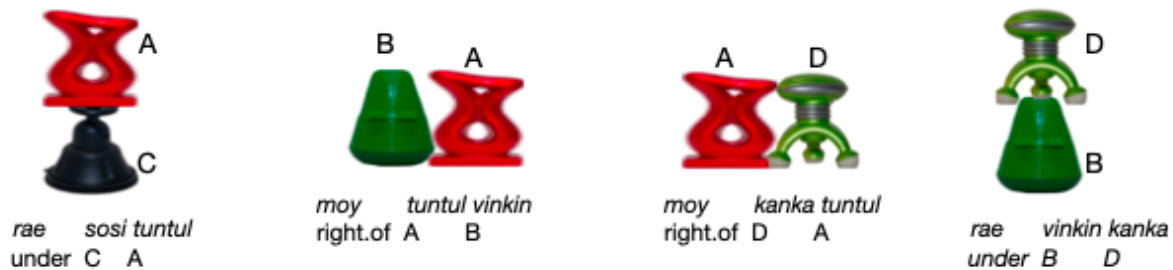


Figure 4.17: Some two-item scenes from Generation 5, Chain K, showing crossed grammar.

As shown in Figure 4.18, a unique rule may be operating in Chain K for adjacent pairs of identical objects: for these, the spatial adposition precedes both. Otherwise, the labels for larger scenes appear consistent with branching syntax.

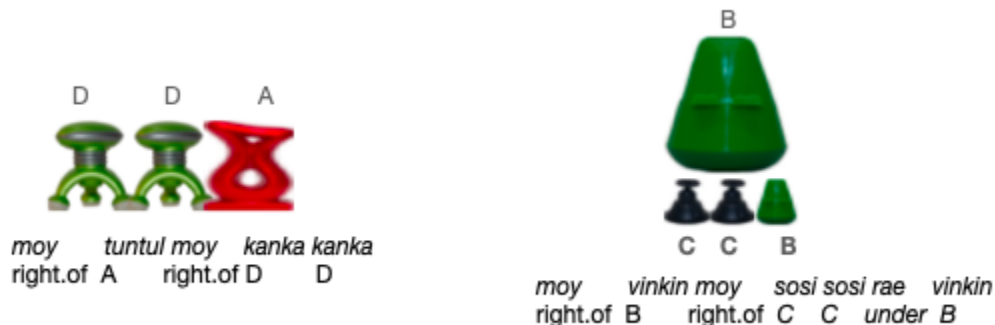


Figure 4.18: Some larger scenes in Generation 5, Chain K.

Other than this chain, which may not have fully stabilized, there were no clear occurrences of crossed grammar in the stable languages. Nor did center-embedding arise and remain stable. The prevalence of branching grammar may have been due to a combination of structural factors (shorter total dependency length) and participants' linguistic backgrounds (all were English speakers). English influence also likely accounts for the prevalence of noun-initial syntax.

One major difficulty which we faced in both this experiment and Experiment 1 was the difficulty of getting clear adposition meanings, which made it hard to narrow down grammars (see appendix figures). Even with training-to-criterion on adposition labels with geometric objects, many participants had to be discarded because adposition meanings given were nonspecific or inconsistent. Seeing a language with randomized word order, or one in which order had not fully stabilized, may have disrupted participants' learned meaning for the adpositions.

4.4. General discussion

Taken together, these experiments are consistent with much psycholinguistic research showing that center-embedding is difficult to learn. However, in the learnability experiment, center-embedding was not more difficult to learn than crossed grammar. The difference between previously seen descriptions, and descriptions generated for unseen items, serves as a metric for how well the grammar was generalized. Here, generalization seemed to be more difficult in the noun-final than noun-initial conditions, and dependency type did not make a difference.

The iterated learning experiment further showed that branching syntax tends to arise “naturally” out of initially unstructured input, and the development of a stable syntax was confirmed (in most chains) by the independent creation of identical descriptions for novel scenes by separate participants. The resulting branching grammars feature shorter dependency lengths, which may have been a factor in preference for branching grammars. Another likely factor was native language influence, as all participants spoke English. In all chains except

three (A, K, and I), the word order was clearly English-like, and in one of the exceptions, head-final branching order (i.e. backwards English) prevailed. In one chain, K, a crossed dependency grammar may have emerged.

The use of artificial adpositions used in English phrases in the adposition training trials (“the sphere is *moy* the other object”) may also have biased participants toward replicating English order. This training was intended to make sure adposition meaning was imparted clearly and consequently to help identify the grammar used by participants, and based on the results of preliminary experiments, it appeared to be necessary because adposition meaning was not evidently inferred from viewing scenes with descriptions.

Despite these caveats, the results provide additional evidence for the somewhat unexpected observation that crossed dependency structure, rarely seen in natural languages, is not harder to learn than the widely-found center-embedded structure. The emergence of a crossed-dependency grammar in one iterated learning chain is particularly interesting, especially in light of the fact that center-embedding grammar was not observed in any. This not only conflicts with the observed patterns in natural languages, but with the ordering of context-free (center-embedding) and context-sensitive (crossed dependency) languages in the Chomsky hierarchy (Partee et al. 1990, Öttl et al. 2015). These results are also significant in light of the fact that this experiment featured meaningful semantic strings, demonstrating that the anomaly of crossed and center-embedded dependencies can arise in a meaningful language-like system as well as in nonsemantic symbol sequences (e.g. DeVries et al. 2008, Uddén et al. 2012). The role of dependency length minimization in learnability is also relevant. A preference for branching dependencies, which shorten dependency length and are widely preferred across natural languages (Hawkins 2004), was strongly confirmed through both experiments. However, an apparent preference for crossed over center-embedded dependencies demonstrates that dependency-length minimization cannot fully account for the patterns observed in our results; while crossed dependencies have shorter maximum length for

each individual dependency, they still generate greater dependency length than branching, and a total dependency length comparable to center-embedding. Some other factor(s) must be at work in both natural language and artificial language and sequence learning. For example, crossed dependency structures may be easier than center-embedded structures because they allow a count-and-match strategy rather than last-in-first-out strategy necessary for center-embedding (Vogel et al. 1996). This is a plausible strategy for nonlinguistic sequence learning, and our findings suggest it may also occur in artificial language learning.

Under the (plausible) assumption that the prevalence of branching dependencies, generally head-initial, was influenced by the shared English language background of our subjects, a useful approach for follow-up studies would be performing comparable studies with speakers of languages such as Japanese and Korean. These languages are head-final and also more tolerant of center-embedding; small-scale corpus studies (Davis forthcoming) suggest that multiple clausal center-embedding is far more common in these languages than in SVO languages such as English.

4.5. Conclusion

We have shown that center-embedded dependency structures are difficult to learn in artificial languages, and do not readily arise through iterated learning (at least with English-speaking participants). On the other hand, a crossed-dependency grammar was no harder to learn than a center-embedding grammar, and there were suggestions in our data that crossed grammars were more likely to be faithfully reproduced. This is surprising given evidence in other artificial language learning tasks that learnability and typological frequency are often aligned, and considering that crossed dependencies are almost nonexistent in natural languages, whereas center-embedded dependencies do appear widely despite the processing difficulties they may present. Branching syntax was found to be easier than either center-embedded or crossed dependencies, which is consistent with language typology and prior experiments, and branching also predominated in the iterated learning results. Crossed

grammar also appeared in the iterated learning experiment, albeit only sporadically and inconsistently in one chain. Why learnability experiments sometimes produce results at odds with language typology remains to be clarified, and our experiment shows this seeming anomaly applies to artificial languages with semantic meaning as well as to nonlinguistic sequence learning.

This chapter has been submitted for publication:

Davis, Emily and Smith, Kenny (forthcoming). The learnability and emergence of dependency structures in an artificial language. To appear in *Journal of Language Evolution*.

The dissertation author was the primary investigator and author of this material.

5. A Natural History of Recursion: Center-embedding outside language and its evolution

5.0. Understanding nonlinguistic center-embedding

In the preceding chapters, I have discussed center-embedding in a linguistic context, specifically with regard to clauses (chapters 1 and 2), and in the context of sequence learning and artificial language learning experiments (3 and 4). The results show that center-embedding in language is contingent upon both universal and language-specific factors, and limited in extent and processability by factors of semantics and time pressure. In the case of sequence learning experiments, center-embedding places burdens on working memory, and is harder to learn (and less likely to emerge) in an artificial language than other dependency structures. However, patterns analogous to syntactic center-embedding – and likely bearing an evolutionary relationship to it – also appear in nonlinguistic sequences of all sorts throughout human cultural artifacts, including complex tasks, music, and visual arts. These nonlinguistic patterns, in human and animal activity, will be explored in this chapter.

In language, semantic meaning allows dependencies to be determined (e.g. between a subject and verb), but no such meaning exists in nonlinguistic contexts. Therefore, center-embedding in nonlinguistic strings is formed by elements that are identical (as in the sequence learning experiments discussed in Chapter 3), perceptually similar, or parallel in some way, as illustrated in the following examples. This results in mirror-symmetric patterns in visual strings, or equivalent patterns in sequences of performance and action, all of which will be discussed in the following subsections of this chapter.

The simplest form of a center-embedded pattern consists of a sequence where two copies of one element, or two elements that match each other in some way, surround a different element, as visually exemplified in (1):

1.

A-B-A

A sequence of this type may be further extended by recursively using the rules of a context-free grammar, as outlined in the Introduction: a simple example of such a rule would be: $B \rightarrow B-C-B$. In sequences generated in this way, the first element corresponds to the last, the second to the penultimate, and so on; a few examples are shown in (2).

2.

A-B-B-A

A-B-C-B-A

A-B-C-D-C-B-A

In center-embedded sequences of this type, the paired elements may either be identical, as in the palindrome examples above, or systematically matched in some way, as in a sequence of brackets like those in (3):

3.

{[()]}

{[(0)]}

Note that these sequences visually exemplify mirror symmetry, a quality which will be discussed further with regard to visual arts in Section 3.1.6. Center-embedding can also be exemplified in auditory or action sequences, including music and narrative. Examples of matched but not identical elements in temporal sequences would include musical passages in the same key, poetic lines that rhyme, or the opening and conclusion of a story in a set of nested narratives (all of which will be discussed in the subsequent sections of this chapter).

Understood in this broader way, center-embedding is not a purely syntactic phenomenon, but appears, at great range and depth, in a variety of domains of human activity, and possibly in some animal behaviors as well. The idea that center-embedding (or recursive structure more generally) occurs beyond language has been observed several times, apparently independently in some cases, and in disciplines including music theory and anthropology (e.g. Hofstadter 1979, Staal 1984, Fitch & Martins 2014). Here I will bring together a number of

relevant observations from diverse areas of science and the humanities, first in human nonlinguistic activities (Section 3.1) and then among animals (Section 3.2), both in naturally occurring activities and in experimental settings.

5.1. Human culture and activities

As I have explored in the preceding chapters, center-embedding is infrequent in language, but is not entirely disfavored. It presents processing difficulties that can be mitigated by several types of linguistic factors (as seen in Chapter 1), is more prevalent and tolerated in SOV than SVO languages (as discussed in Chapter 2), and also presents challenges in sequence and artificial language learning (Chapters 3 and 4). In the following sections I will explore center-embedding beyond syntax, starting with the higher-level linguistic structures of discourse (5.1.1), literary and narrative structure (5.1.2), and poetic structures like rhyme and refrains (5.1.3), and then moving on to nonlinguistic domains. Center-embedding occurs in the structure of rituals (5.1.4), a manifestation which is likely closely related to its deep evolutionary origins. From rituals, which stand at the center of the embedding question, I move on to other areas of nonlinguistic activity, starting with the pervasive appearance of center-embedding in music (5.1.5). The widely occurring bilateral symmetries in architecture and other forms of visual art (5.1.6) also bear similarities to the center-embedded patterns in other domains such as music, including specific palindromic and “bracketed” structures. Finally, everyday household activities and other tasks can be analyzed as presenting center-embedded structures, in which sequences of actions are nested inside other such sequences (5.1.7). Circling back to language, I propose that linguistic recursion, and center-embedding in particular, may be an exaptation from embedded action sequences (ritual as well as utilitarian), with discourse and poetic structures potentially representing “missing links.”

5.1.1. Discourse

Looking beyond the level of individual sentences, we find center-embedding in the structure of multi-person conversations, and in this domain it may reach greater depths than any one sentence allows. Center-embedded structures appear in interactive discourse, in the form of nested adjacency pairs (Levinson 2013, 2014). For example, the conversation between a waiter and a customer in Figure 5.1 (Levinson 2013, original example from Merritt 1976) has three layers of embedded adjacency pairs formed by questions and requests for repair, within the main request and answer (notated as 0):

S:	Next	(Request to order: 0)
0 C:	Roast beef on rye	(Order: 0)
1 S:	Mustard or mayonnaise?	(Q: 1)
2 C:	Excuse me?	(Repair initiator: 2)
3 S:	What?	(Repair: 3)
3 C:	Excuse me, I didn't hear what you said	(Repair: 3)
1 S:	Do you want mustard or mayonnaise?	(Repair: 2)
C:	Mustard please.	(A: 1)
0 S:	((provides))	(Compliance with order: 0)

Figure 5.1: Nested adjacency pairs in discourse (Levinson 2013)

In discourses like this, an inner adjacency pair must be resolved (e.g. a mishearing must be corrected) before the outer one can be resumed, generating a long-distance dependency between the components of the outer pair, much like the dependency in a clause that must be “held open” while a center-embedded clause is processed. Levinson (2013:156-7) cites still more complex examples, including a discourse from Schegloff (2007) that he analyzes as having six layers of embedding, though he provides this example only in truncated form. It is clear, however, that embedding in discourse can reach deeper levels than in individual sentences. As we saw in Chapter 2, sentences with three center-embedded clauses are extremely rare in writing and nonexistent or nearly so in spontaneous speech, although a few scattered examples can be found (Levinson 2014, Karlsson 2007).

Levinson (2013) also presents an account for how recursive structure might have “filtered down” from multi-person discourse into the syntax of individual sentences. Specifically, he attributes the emergence of syntactic embedding to pragmatic construals of paratactically joined sentences. For example, the pair of sentences “Buy a ticket! Win a thousand dollars!” may be construed to mean “If you buy a ticket, then you can win a thousand dollars” (Levinson 2014). He further argues that discourse embedding, which can reach deeper than syntactic embedding, comes from a general cognitive task-planning ability because “indefinite centre embedding in interactive discourse is construed over speech acts – actions in linguistic clothing” (Levinson 2014:11). This discourse would follow a subgoal structure akin to that discussed by Pulvermüller (2014), further discussed in Section 3.1.6. These speech-acts, utterances used to accomplish some goal, have counterparts in normal actions – for example, the “conversational turn” that concludes the service discourse in Figure 5.1 is the wordless offering of a sandwich. Therefore, the patterns involved in (solitary or joint) task planning are transferred to speech acts, in a case of exaptation (Gould & Vrba 1982).

However, some aspects of Levinson’s proposal are problematic, as explored by Legate et al. (2013). While Levinson seems to assume that conversational adjacency pairs are always nested, Legate et al. (2013) note that they can also be “interdigitated” – a form akin to crossed dependencies, not center-embedded, as in (4):

4.

A. Where are my keys?

B. Oh, are you ready to leave now?

B. They’re on the kitchen table,

A. Yes, I’m ready to leave. (Legate et al. 2013: 524, ex. 12)

Therefore, Legate et al. argue, there is no strong support for Levinson’s idea that discourse exclusively or preferentially follows recursively center-embedded patterns. However, the existence of other dependency structures in discourse does not undermine the claim that center-embedded structures exist, any more than the (rare) appearance of crossed

dependencies in syntax (see Chapter 4) means that center-embedding is not a recurring structure. Further qualitative and quantitative investigation would be necessary to determine the prevalence of different dependency forms in discourse adjacency pairs.

Legate et al. (2013) also argue that embedding in discourse does not appear to be unlimited as Levinson suggests, as demonstrated by the difficult and unnatural appearance of (5) (Legate et al. 2013):

5.

- A. May I have a bottle of Mich?
- B. Are you 21?
 - A. Is that the drinking age around here?
 - B. Yes.
 - A. No.
- B. No. (Legate et al. 2013: 525, ex. 13)

However, a set of three such conversational adjacency pairs seems acceptable if question and answer pairs are clearly indicated, as in (6):

6.

- A. May I have a bottle of Mich?
- B. Are you 21?
 - A. Is that the drinking age around here?
 - B. Yes.
 - A. Unfortunately, I'm not 21 yet.
- B. Sorry, I can't sell you a beer. (Legate et al. 2013: 525, ex. 14)

Legate et al. (2013) take this discrepancy to suggest that discourse-level center-embedding is not as unconstrained as Levinson proposes. However, if taken in the context of the factors affecting syntactic center-embedding, this observation of limited depth provides a parallel to similarity-based interference – center-embedded sentences are more comprehensible and acceptable if the noun and verb phrases are not too similar in morphology, syntax, and/or semantics (see Chapter 1, Section 2.4). As some of Levinson's more complex examples demonstrate, discourse embedding may indeed be less limited than syntactic embedding, if some equivalent to the syntactic facilitating factors are present. For example, in

Figure 5.1, no exact repetitions or chains of “yes” and “no” are present, as is the case in Legate et al.’s constructed example. In general, their counterarguments to the idea of embedding in discourse do not seem to hold up, and exemplify the same type of overgeneralization and dismissal that are commonly repeated with regard to syntactic center-embedding, i.e. the notion that center-embedding is always difficult.

I now turn to another area of language use where embedded structures on extra-sentential levels may be even deeper and more elaborated than in everyday discourse – rhetorical, poetic, and literary forms that feature center-embedding.

5.1.2. Literature

A second linguistic but non-syntactic domain in which center-embedded structure appears involves the structures found in narratives and poetry – specifically “frame” or “ring” patterns in narratives – and poetic structures such as rhyme and meter. Here I attempt to bring together some of the wide-ranging observations of the extent and variety of nested constructions in literature.

This and the next subsection concern a class of rhetorical or poetic devices that manifest at different levels in narratives and poetry, known by various terms, including chiasmus (Lissner 2007, Welch 1981), ring composition (van Otterlo 1944), frame narratives (Oertel 1898), omphalos (Watkins 1995), or wheel construction (Forte & Smith 2014). These structures involve patterns which can be formalized as A-B-A, A-B-B-A, et cetera, featuring nested pairs of units which can be matched to each other by similarities in meaning, grammatical structure, and so on, in some cases “bracketing” off a central element. In what Forte and Smith (2014: 57) call a *wheel composition*, the center of the whole construction forms a turning point in the narrative or theme, and the importance of this center point is emphasized by its framing.

The scope of these structures can be anywhere from a short line to an entire epic poem, and in some cases patterns occur in the same work on multiple levels – e.g. both the work as a

whole, and each subsection of the work, follows a ring pattern. In what follows, I will move from small-scale chiasmus structures (involving individual words or concepts) in Section 1.2.1, to the “ring” and “frame” structures that span whole epics (1.2.2), and the concept of nested narrative (1.2.3) and then discuss poetic rhyme and meter patterns fitting the same general pattern (1.2.4). I will also discuss the possible connections between poetic and narrative center-embedding and similar patterns in rituals, as a lead-in to the following section.

5.1.2.1. The chiasmus: a mirrored rhetorical figure

Nested structures may appear on a small scale in the form of the rhetorical figure called *chiasmus*. In a chiasmus, key words or concepts form nested pairs (AB/BA) or longer palindromic structures (e.g. ABC/CBA) as in the lines of English poetry in (7), from Welch (1981: 9), many proverbs and aphorisms (8), and in the Latin epigram in (9):

7. A **wit** with **dunces**, and a **dunce** with **wits** (Alexander Pope, *Dunciad*)

Flowers are **lovely**, **love** is **flowerlike** (Samuel Taylor Coleridge, *Youth and Age*)

8. **Cheaters never win** and **winners never cheat**

A **place** for **everything** and **everything** in its **place**

All is for the **best** in the **best** of **all** possible worlds (Martin, n.d.)

- 9.

Non am-o te, Sabid-i, nec **pos-sum dic-ere** quare.
NEG love-1sg 2sg.ACC Sabidius-VOC nor can-1sg say-INF why

Hoc tantum **pos-sum dic-ere: non am-o te**.
this.ACC much.ACC can-1sg say-INF NEG love-1sg 2sg.ACC

“I do not love you, Sabidius. I can not say why. This much I can say: I do not love you.” (Martial, Epigram 32).

Instances of chiasmic proverbs and aphorisms like these are widespread across different languages and cultures (Grausso 2020). In these cases, key words or concepts (e.g. *love/flower*, *cheat/never/win*, *non amo te / possum dicere*) form a nested palindromic pattern, such as AB/BA or ABC/CBA, in the two halves of the line or epigram.

Nested patterns can also occur at a more abstract level, as in (10), the short poem “Fog” by Carl Sandburg (Ross 1991):

10.
The fog comes
 on little cat feet.
 It sits looking
 over harbor and city
 on silent haunches
and then moves on.

Here the first and final line (“the fog comes... and then moves on”) form a matched pair of actions, the second echoes the penultimate in its use of the preposition “on” and a reference to feline anatomy, and lines 3-4 form a coherent syntactic unit, among other patterns (Ross 1991).

A similar conceptual centered structure – also known as the “omphalos” or “wheel” form – occurs in “riddle” hymns of Vedic literature (Brereton 1999, Forte & Smith 2014, Jamison 2004, Brereton & Jamison 2020: 152), and as will be discussed in the following section (3.1.4), this poetic structure may be linked to ritual. These poems address a dilemma or problem of some sort, such as the efficacy of ritual or the harmony of the cosmos, and the middle element of the nested structure reveals a solution to the central enigma, surrounded by pairs of lines that parallel each other in meaning as well as shared grammatical and lexical features (Forte & Smith 2014). In one example from the *Rg Veda* described by Forte & Smith (2014: 65), reproduced here as (11), this central point is explicitly associated with the navel (omphalos) and the center of the universe, and is surrounded by nested pairs of lines presenting problems or fears and their solutions:

11.
1–2: cosmic and earthly order
 3–4: fears about maintaining order
 5–6: questions about fate of ritual offerings
 7–8: more anguish; thoughts compared to wolves, co-wives, mice
 9–10: *omphalos: cosmic vision*
 11: wolf kept at bay
 12: effective words reestablished
 13–5: gods take charge of sacrifice
16–7: order restored

Figure 5.2 shows another example from the Rig Veda in transliteration, with highlighting indicating matching grammatical forms and words that constitute the ring structure. This poem, Hymn 10.125, is written in the voice of the personification of speech. The elements highlighted in red are first-person nominative forms which “bracket off” the central couplet, in which other first-person forms (underlined in red) are used instead. Other repeated roots including *vadāmi* “I speak” also appear as bracketing devices around the center (S. Jamison, personal communication).

X.125 (951) Speech

10.125.01a	ahám rudrébhir vásubhiś carāmy ahám ādityaír utá viśvádevaiḥ
10.125.01c	ahám mitráváruṇobhá bibharmy ahám indrāgní ahám aśvínobhá
10.125.02a	ahám sómam āhanásam bibharmy ahám tváṣṭāram utá pūṣāṇam bhágam
10.125.02c	ahám dadhāmi dráviṇam havíṣmate suprávyè yájamānāya sunvaté
10.125.03a	ahám ráṣṭrī saṃgāmanī vásūnām cikítuṣī prathamā yajñíyānām
10.125.03c	tám mā devá vy ādadhuḥ purutrā bhūriṣṭhātrām bhūry āveśāyantīm
10.125.04a	māyā só ánnam atti yó vipásyati yáḥ práñiti yá īm śṛṇóty uktám
10.125.04c	amantávo mām tá úpa kṣiyanti śrudhí śruta śraddhivám te vadāmi
10.125.05a	ahám evá svayám idám vadāmi júṣṭam devébhir utá mánuṣebhiḥ
10.125.05c	yám kāmāye tám-tam ugrám kṛṇomi tám brahmāṇam tám íṣim tám sumedhám
10.125.06a	ahám rudráya dhánur á tanomi brahmadvíṣe śárave hántavá u
10.125.06ca	hám jánāya samádam kṛṇomy ahám dyāvāpṛthiví á viveśa
10.125.07a	ahám suve pitáram asya mūrdhán māmá yónir apsv àntáḥ samudré
10.125.07c	táto ví tiṣṭhe bhúvanānu vísvotámúm dyám varṣmánópa sprśāmi
10.125.08a	ahám evá vāta iva prá vāmy ārabhamāṇā bhúvanāni vísvā
10.125.08c	paró divá pará ená pṛthivyaítávatī mahiná sám babhūva

Figure 5.2: Hymn 10.125 of the Rig Veda, in transliterated Sanskrit, with highlighting showing parallel words and grammatical structures (first-person forms) that form a ring structure. (S. Jamison, personal communication.)

The prominent role of center-embedding in Vedic ritual and culture, and the possible greater implications of ritual structure for the evolution of linguistic center-embedding, will be discussed further below in Section 5.1.4.

5.1.2.2. Larger-scale ring structures

The same general pattern can be elaborated at greater length and depth over higher levels of a text, with the units constituting entire narrative episodes that echo or parallel each other, and in this form it is quite pervasive across epic narratives in Western and other cultures. Douglas (2007: 37) describes such “ring-within-ring” constructions, which feature palindromes within palindromes – center-embedded patterns such as ABCBA and ABACABA. As will be discussed below, these patterns also have counterparts in music and visual arts, illustrating the remarkable breadth of center-embedded structures in human culture.

Examples of ring constructions on multiple scales can be found in ancient epic poetry, e.g. the *Rg Veda* (Jamison 2004), Homer (Whitman 1965, Nimis 1999, Stanley 2014), the Bible (Douglas 2007, Breck & Lock 1994, Wenham 1978), medieval European epics such as *Roland* and *Beowulf* (Niles 1973, Niles 1979, Young 1997), Shakespeare’s plays (Rose 1972), along with other ancient literary works (Welch 1981), as well as in oral narrative poetry in modern-day non-literate cultures (Lord 2000). Peterson (1976), in offering an overview of this literary structure, states: “...such phenomena have gone without explicit recognition until this century, but they are, I believe, impossible to deny – like the circulation of the blood, no less real for having been long undiscovered.”¹ For example, (12) represents the opening and conclusion of *Beowulf* (Niles 1979), and comparable structures occur throughout the poem:

¹ However, see Dane (1993) for a critique of the over-application of ring composition in analyses of classical and medieval literature.

12.

Prologue

A: Panegyric for Scyld

B: Scyld's funeral

C: History of Danes before Hrothgar

D: Hrothgar's order to build Heorot

Epilogue

D': Beowulf's order to build his barrow

C': History of Geats after Beowulf ("messenger's prophecy")

B': Beowulf's funeral

A': Eulogy for Beowulf

In addition to framing off an important section of the narrative, a ring composition may center around a key turning point, as in (13) from Niles (1973) in the medieval French *The Song of Roland*. Here, the lament for Roland's death marks a transition from victory to defeat, which in turn is "bracketed" by several other parallel episodes, such as the approach of the Saracens and that of the Franks:

13.

Saracens assemble, pledge to destroy Franks

Saracens arm and approach with grailles

First debate over blowing of horn

General combat: Franks victorious

Lament in nature for death of Roland

General combat: Franks defeated

Second debate over blowing of horn

Charles' Franks arm and approach with grailles

Decimation of rear guard; Saracens dispersed.

Ring compositions can occur at multiple scales within the same work, producing recursively nested rings within rings. As Niles (1973) puts it:

The whole of *La Chanson de Roland*, in fact, may be described fairly well as a single great ring which is composed in turn of a number of lesser rings. As has been suggested elsewhere, the main episodes of the poem, like parts of a Romanesque cathedral, are set into careful balance with one another.²

In other classical examples within the "Western canon", both the individual books of the *Iliad* and the poem as a whole follow ring structures (Whitman 1965f: 367), and multilevel patterns of the

² Regarding the "cathedral" analogy, I will return to the manifestations of center-embedded symmetry in visual art and architecture below in Section 3.1.5.

same type can be found in the Bible (Douglas 2007: xiv), and Shakespeare (Rose 1972; see the following section and especially Figure 5.3).³

Turning to modern media with influences from ancient epics, the Star Wars prequels and original trilogy can also be analyzed as exemplifying ring structure: the two trilogies mirror each other in a pattern formalized as A B C C' B' A' (Klimo 2014; see Figure 5.3).

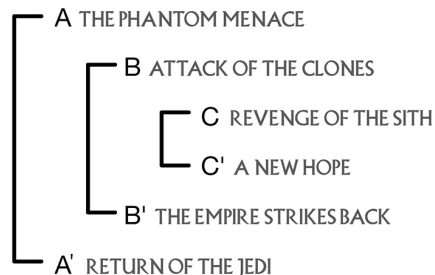


Figure 5.3: Ring structure in the Star Wars prequels (top half, ABC) and original trilogy (bottom half, C'B'A'), from Klimo (2014).

So far, I have discussed examples of ring constructions involving identical or parallel elements within one unified narrative, e.g. in the prologue and epilogue of a poem like *Beowulf*. However, narratives themselves can also be nested one inside another, as I will turn to next.

5.1.2.3. Narratives within narratives: The frame story

Literary center-embedding may also manifest as one narrative contained within another (see Figure 5.4 for an example from Shakespeare). In this case, one story serves as the frame for another, which may be a story told by a character (e.g. in the *Canterbury Tales*), a dream, a flashback, a play within a play such as in *Hamlet*, et cetera (Douglas 2007: 18), forming recursive structures that can be continued at great depth. These so-called frame-narratives are a widespread literary device (see e.g. Hofstadter 1979 for further discussion), and of great antiquity.

³ Stanley (2014:11) also observes instances of “interlocking” constructions in Homer, where parts of two parallel narratives are interleaved rather than nested. This form could be summarized as A1 B1 A2 B2 A3 B3, where A and B are the separate narratives and the numbers mark parallel incidents. Structurally, this form is analogous to crossed dependencies (for more on which see Chapter 4).

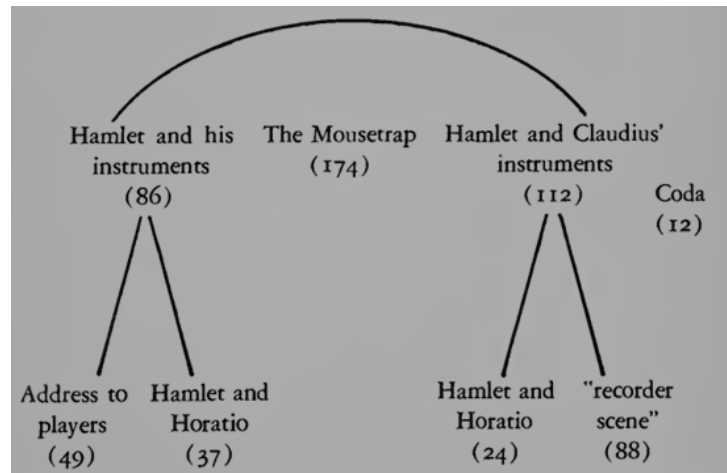


Figure 5.4: Nested structure in a scene of Shakespeare's *Hamlet* (Rose 1972: 113). Note that "The Mousetrap" is also a play performed within the play, an example of a nested narrative.

The *Mahābhārata*, a sacred classic of Hindu literature, is the earliest known example of a nested narrative (Minkowski 1989: 412). Its outermost frame story is set at a multi-day sacrifice ritual (see Section 5.1.4 below on ritual structure), with breaks for the recitation of stories, and these stories contain even deeper levels of nested narratives (Minkowski 1989). The embedded stories are set off by a variety of bracketing devices, including the arrival of a new narrator, requests from the audience to elaborate a story, and expressions of hospitality, all of which follow consistent grammatical and lexical formulae (Minkowski 1989: 407ff). Another well-known and very complex example of nested narrative is the *Arabian Nights* or *One Thousand And One Nights*, which may have been influenced by the *Mahābhārata* and other Vedic nested narratives (Irwin 1994).

In this subsection, I have described some examples of center-embedded patterns in proverbs and narratives, in which the units forming palindromic patterns may be similar or matching words, incidents in a narrative, general themes and imagery, or the beginnings and ends of stories. I now turn to another manifestation of non-syntactic center-embedding in (often semantically meaningless) poetic forms of rhyme and meter.

5.1.3. Poetic structures: refrains and rhymes

Center-embedded structures may also occur in the phonological structures featured in mantras and poetry, such as in rhyme, alliteration, and metrical patterns. Mantras, specifically those used in rituals or meditation, are often phonetically intricate but lacking semantic meaning, or consist of meaningful sentences rearranged for their use in ritual contexts according to rules of permutation, with no regard for the original meaning (Staal 1979:20, 1985, 1989). Staal (1989: 282) suggests that mantras of this type could be an evolutionary link between ritual and language, and that the structures of poetry might constitute a link between mantras and normal language. Support for this idea comes from the presence of the same types of embedded structures in poetry as in ritual and music⁴: rhyme schemes that form mirrored patterns, poems that begin and end with the same (often semantically meaningless) refrain, and more abstract instances of center-embedding in the design of repeated words in a medieval poetic form.

As previously mentioned with regard to the *Mahābhārata* and other nested narratives, various “bracketing” devices may be used to set off “levels” of a nested narrative, such as formulaic expressions following systematic grammatical patterns. Similar forms of bracketing occur, without semantic meaning, in poetry. In addition to their generally intricate structures, poetic rhyme and meter schemes may also exemplify center-embedded structures in the same way as music and narratives; Forte & Smith (2014) discuss examples of palindromic meter from ancient Greek and Indic poetry, and patterns of this type are common in English literature as well. A center-embedded rhyme structure (ABCCBA) can be seen in (14), a stanza from Robert Browning’s “Meeting at Night” (from Gardner 2005: 40):

⁴ I will discuss Staal’s observations concerning ritual more extensively in the following subsection (3.1.3), and music in the next subsection (3.1.4).

14.

The grey sea and the long black land;
And the yellow half-moon large and low;
And the startled little waves that leap
In fiery ringlets from their sleep,
As I gain the cove with pushing prow,
And quench its speed i' the slushy sand.

There are also several examples of traditional songs or rhymes which are “bracketed” by a nonsense refrain occurring at the beginning and end of a stanza, such as the English “Hickory Dickory Dock” and “Diddle Diddle Dumpling,” and the Italian “Ambarabà cicci coccò” (Verwert 2014). The traditional *karintaa* chants of the Nanti people of Peru show a similar center-embedded structure: a string of nonsense syllables such as “kee kage kage ga” both precedes and follows a taunting song (Michael 2004). Note also that in (15), the penultimate line echoes the second in its meaning and morphology, creating another pair of brackets:

15. kee kage kagega kee kage kagega

pikamantasanotake
you.really.told.him

iintii hobatyo kaemakagakena
it.is Juan (who).called.me

piikamantakero
you.told.her

kee kage kagega kee kage kagega

“You really told him, Juan called me, you told her.” (Michael 2004).

Besides appearing in rhyme and metric patterns, center-embedding also manifests more abstractly in the sestina, a poetic form originating in medieval Italy. This form is based on a list of six words which occur at the ends of lines in each stanza, in different permutations. The order of words in the second stanza is determined by rearranging the original end-line words of the first stanza as follows: 6 1 5 2 4 3, a sequence consisting of three pairs of “brackets” working inward (Preminger et al. 1993: 1146). To generate the end-line words for the third stanza, the

same procedure is applied to the end-line words of the second, and so on. This process is illustrated in Figure 5.5.

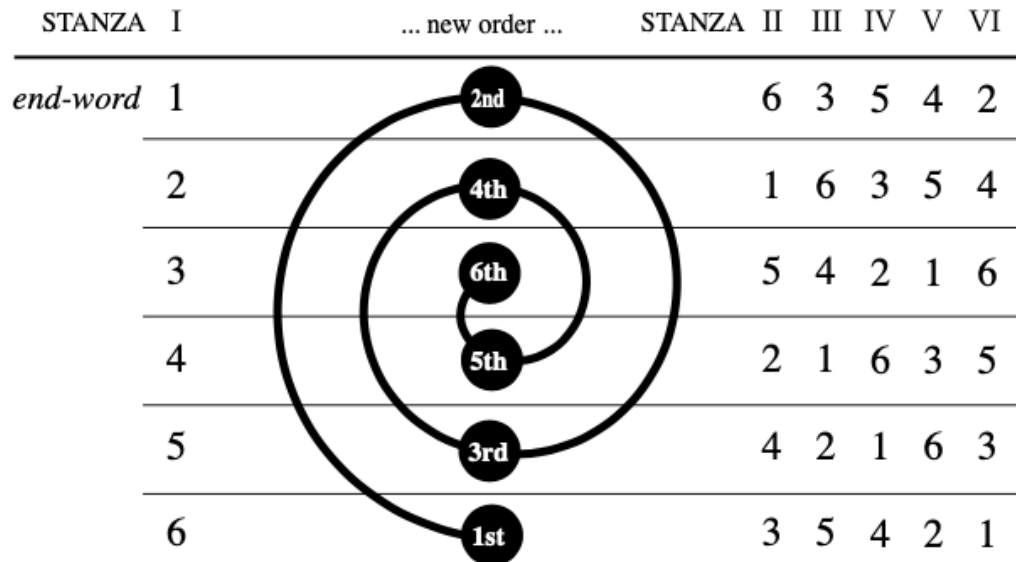


Figure 5.5: Patterns of end-words in a sestina. Note how the end-line words for each stanza are chosen by “bracketing” inward the sequence in the preceding stanza (6 1, 5 2...), producing the inward spiral pattern. (Diagram from Wikipedia, by user Phil Wink. Public domain.)

Like the repetition of words and concepts in chiasmus patterns discussed in 5.1.2, rhyme and meter may also help facilitate memory of long poetic passages, as well as producing aesthetically pleasing balance and symmetry.

The prevalence of center-embedded structures in literature and discourse, as in syntax, raises the question of their deeper cultural and cognitive basis. As previously discussed, nested narratives occur in Vedic literature and are closely tied up with ritual: a ritual may serve as a framework for the entire narrative (Minkowski 1989) or a narrative may explicate the structure of a ritual (Witzel 1987). On this basis, these authors suggest that this embedded literary structure actually derives from rituals. The nature of these ritual structures and their possible relationship to recursion in language is discussed in the following section.

5.1.3. Ritual structure: a possible origin of center-embedding

In a series of papers on Vedic ritual, the Indologist Frits Staal (1979, 1980, 1984ab, 1990) observed intricate patterns of embedding in these ancient and elaborate performances and observed striking parallels to syntactic embedding. Specifically, Staal noted that performances of one Vedic ritual can be embedded in another (Staal 1979:16), much like the constituents of a sentence; also like embedded phrases and clauses, the embedded rituals may undergo modifications specific to their surrounding context (Staal 1990: 99). A complex example is shown in Figure 5.6, where, for example, performance P is center-embedded inside A and an instance of D inside P.

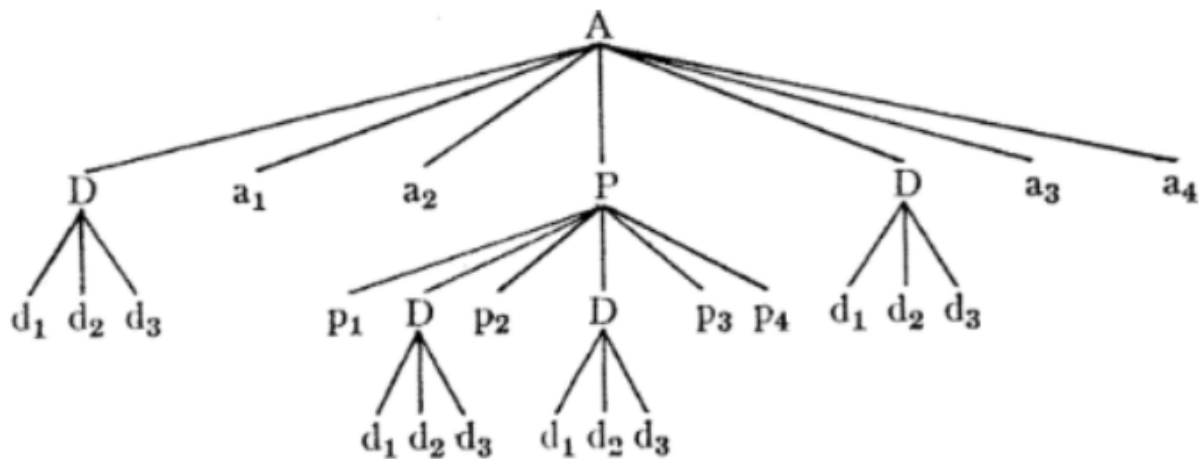


Figure 5.6: Ritual structure (Staal 1979)

Another striking parallel between ritual and syntax involves “bookended” or “bracketed” structures: a ritual may be preceded and followed by rites which match or correspond to each other in some way (Staal 1980: 133); these resemble long-distance dependencies in language, of the sort explored in Chapters 1 and 2. (16), with three levels of matched counterpart actions, is from Staal (2008: 230):

16.

D: constructing the enclosure

C: entering the enclosure
B: preparing the fire
A: making an offering
B: covering the fire
C: leaving the enclosure
D: destroying the enclosure

Note also the similarities between this bracketed ritual structure and the narrative and poetic structures described in the previous sections: the pairs of matching actions at each level complete or “rhyme” with each other. I will return to similar patterns of “bracketing” in everyday activities in Section 5.1.7 below.

Staal argues that this parallel suggests that the structure of ritual is in fact the origin of syntax (1979: 19). In support of this claim Staal notes that “syntax is the part of language which stands most in need of explanation” – i.e. the hardest to explain as an adaptation, because syntax seems needlessly complex and not necessarily well-suited for communication. This anomaly implies that syntax was exapted from another domain onto language, and ritual provides a possible source domain. As discussed in the previous sections (5.1-3), discourse, poetry, and narratives also involve center-embedded structures, and may be understood as “missing links” between ritualized activity and linguistic syntax.

Staal’s observation on the adaptation of syntactic structure from ritual to language applies particularly well to center-embedding, one syntactic feature which presents particular real-time processing challenges, as explored in the previous chapters. While rituals unfold over a far longer time frame than sentences, the same sort of embedded structures occur in both (Staal 1980: 134-5). This difference in the time frames of ritual and syntax is significant for the relatively “vestigial” state of linguistic center-embedding. As explored in Chapter 1 and 2, center-embedding in language is limited in depth and requires facilitating factors (generally speaking, a reduction of semantic content within embedded clauses) to be easily processable. Staal (loc. cit) further suggests that the limited depth of center-embedding in syntax results from the pressures of short-term processing, which do not apply to rituals spanning hours or even

days. This time pressure factor could therefore account for the prevalence of right- or left-branching dependency structures in languages and the use of syntactic rules or movement to avoid center-embedding (see Chapter 1 Section 1), all of which decrease dependency length and the number of dependencies that must be held open in working memory (both factors contributing to the difficulty of center-embedding). Staal's hypothesis is also supported by the observation of Karlsson (2007, 2020) that center-embedding is more prevalent and deeper in written than in spoken language; this is because writing allows for greater planning and reflection than on-line discourse. As I will discuss further below(5.1.7) in relation to other domains of human activity, the semantic content of language may also contribute to the “vestigial” state of linguistic center-embedding.

We have seen how the embedded structure of rituals parallels and may have fostered similar nested structures in narratives, and now I will move on to other forms of human artistry and activity. Embedded structures occur in music (Section 5.1.5), visual art (Section 5.1.6), and complex task planning (Section 5.1.7), all of which lack semantics.

5.1.5. Music

Like narratives, poetic structures, and rituals, music features center-embedded patterns exemplifying forms such as A-B-A, and many more complex palindromic structures. These structures can occur on different levels, ranging from repetitions of individual notes to higher-level patterns such as corresponding passages in the same key. The appearance of center-embedding in music carries some implications for the evolution of center-embedding and linguistic recursion, given the plausible evolutionary relationships between music and language.

The idea of a cognitive and evolutionary link between human language and music has been a subject of speculation since (at least) Charles Darwin (1871), and still attracts considerable interest from linguistics and related disciplines (e.g. Lerdahl & Jackendoff 1983, Patel 2010, Rebuschat et al. 2012, Dienes et al. 2012, Koelsch et al. 2013). Based on the

ubiquity of music in human culture, some anthropologists have argued that music predates language evolutionarily (Jordania 2011, Lewis 2018) and that early human protolanguage may have resembled music (e.g. Mithen 2005). These speculations on music parallel Staal's proposal for the prelinguistic origins of ritual and its structured but meaningless vocalizations – music, too, is involved in ritual and displays similar types of embedded structures.

There is also cultural evidence for a connection between music and ritual, which suggests a plausible evolutionary link between these behaviors (Lewis 2018). As Merker (1999: 66) notes, many languages subsume music, dance, and poetry along with rituals under one cover term – and as noted in Section 5.1.3, poetry also involves center-embedding in patterns such as rhyme schemes. Similarly, Lewis (2018) has suggested, based on observations of ritual and music among the Bayaka hunter-gatherers, that coordinated group rituals involving (semantically meaningless) group vocalization may predate language. This fits neatly with Staal's observation that rituals also often feature structured vocal activity without semantic content in the form of mantras, mentioned above (5.1.3) in relation to poetic structures without semantic meaning. Anthropologists and musicologists including Merker (1999, 2009) and Jordania (2011) have speculated that ritual group vocalizations may have emerged before the advent of language as a way of coordinating activity and amplifying the reach of calls, e.g. for mate attraction, territorial defense, or frightening off predators. The idea of a common evolutionary origin shared by language, music, and ritual is supported by the structures shared across these activities, as well as by their role in social cohesion. I will elaborate on some of these structural properties in (specifically Western) music below.

In light of its connections to group ritual activity, it is not surprising that music shows center-embedded structures much like those in rituals and narratives, in addition to hierarchical structures more generally. ABA structures, exemplifying the simplest form of center-embedding, are widespread in musical compositions in various instantiations, and are generally known as *ternary form*. These structures have also been observed to parallel those of literature (Porter

1971), namely the “ring” and “nested narrative” constructions described above in Section 5.1.2. The elements of this mirrored structure can be notes, keys, or larger motifs or themes, which may be either identical, or correspond to each other systematically in some way. In discussing the parallels among ritual, music, and syntax, Staal (1984b:25) observes that musical phrases often end with a repeat of the initial note, and similarly that longer compositions frequently begin and end with the same key, or end with a variation on the opening theme. This ternary form appears in Gregorian chant, minuets, rondos, and sonatas, among other musical varieties, which I will now discuss in more detail.

The basic ABA ternary form, exemplifying the simplest center-embedded pattern, can also be elaborated through recursive rules producing more elaborate palindromic and embedded structures (Rohrmeier et al. 2015). For example, “arch” compositions may feature one theme nested inside another, forming an ABCBA pattern. The ternary also forms the basis for the more elaborate compound ternary form ABACABA (DeVoto 2017, Naylor n.d). In an ABACABA structure, two ABA units are joined with a central motif C, forming a longer, self-similar palindrome (DeVoto 2017). The minuet and trio form is another elaboration on the ternary form, consisting of a ternary formed from other ternaries: ABA CDC ABA. Examples of these forms are diagrammed in Figure 5.7.

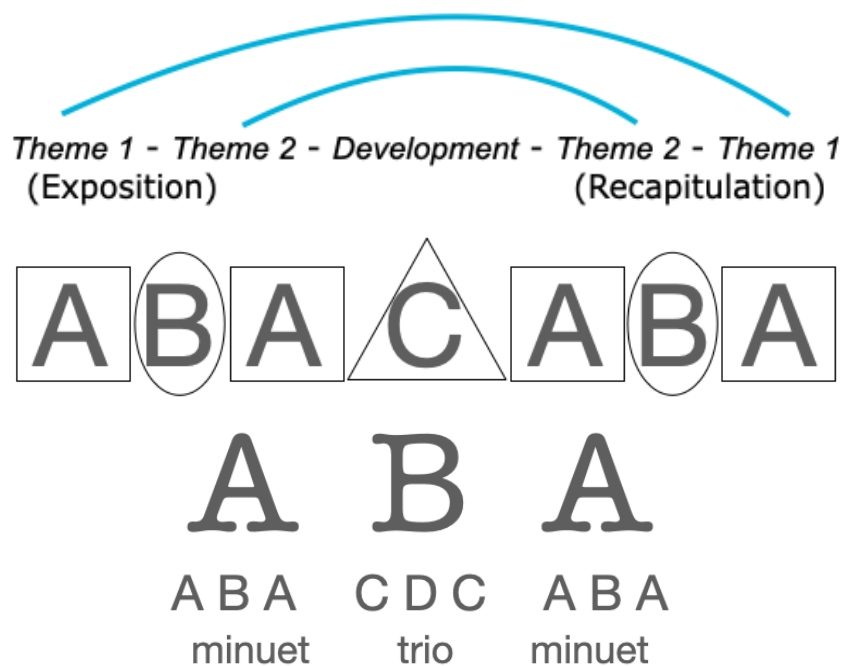


Figure 5.7: Center-embedded musical structures: “Arch Form”, rondo form (after <https://wmich.edu/musicgradexamprep/ModernTerms.html>), and minuet and trio form. Note how the larger structure of the composition and the individual elements ABA/CDC are both center-embedded structures.

Other musical palindromic structures also occur; Staal (1984b: 26ff) attests several examples, which he refers to as “palyndrome,” and “retrograde or mirror” composition.

Palindromic note-by-note structures are uncommon, but examples include Haydn’s symphony 47 and the interlude from Alban Berg’s opera “Lulu” (Figure 5.8); this whole opera also shows a palindromic narrative structure (Reich 1936: 390).

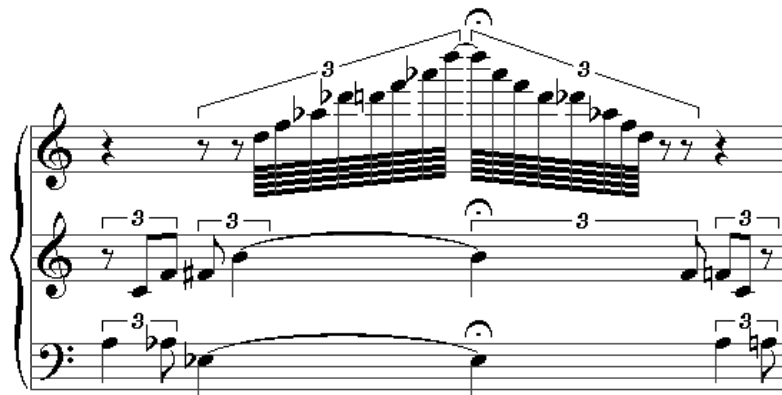


Figure 5.8: Musical palindrome at the central point of Alban Berg’s “Lulu.” Image in public domain.

This structure can be formalized more generally as in (17), which illustrates how the pattern may be extended indefinitely:

17.

$A_1 \dots A_{N-1} A_N N_{N-1} \dots A_1$ (Staal 1990: 169)

Hofstadter (1979: 129-130) similarly discusses how complex nested key changes can be modeled as a push-down stack. In a structure with a palindromic form such as ABCBA or ABACABA, new keys (or notes, themes, et cetera) are pushed onto the stack as they are introduced, and then popped off the stack when they resume. Rohrmeier et al. (2015) analyzed nested patterns like these as following a context-free grammar, i.e. one which allows for the insertion of dependency sequences into other such sequences.

Music, like other ritual action sequences, seems to allow more pervasive and deeper center-embedding than does language. As discussed in the previous accounts of linguistic center-embedding (see Chapter 1), one major factor in the difficulty of processing center-embedding is semantic content – the presence of more semantically complex nouns or verbs which introduce new discourse referents in embedded clauses makes the whole structure harder to understand and less acceptable. As a result, center-embedding is restricted in language: sentences with more than two center-embedded clauses are quite infrequent. Music, however, may allow more extensive and deeper center-embeddings because it lacks semantic content.⁵

One question not fully resolved is whether structures like the palindromes and embedded themes discussed in this section are universal across musical traditions. Most research on the topic concerns Western music, although similar patterns are observed in the North Indian musical tradition (Widdess 1981). Therefore, whether embedded patterns are

⁵ Although lacking semantic content, music can feature iconic meaning, e.g. by imitating sounds such as birdsong or thunder, and can convey emotion holistically. See for example Staal (1984b: 33) and Apel (1970: 696ff) on program music (which features nonmusical sounds as part of the composition), and Bedoya et al. (2021) on how music expresses emotion in general.

universal across musical traditions is not entirely certain, but they are definitely pervasive at least within the Western classical tradition.

In the next section I will move to another area of human activity in which symmetric patterns analogous to center-embedding do in fact appear to be universal – the visual arts, including architecture.

5.1.6. Visual arts: from temples to emojis

Center-embedding also occurs in the visual arts, where elements may be arranged in mirrored symmetrical patterns, and recurs across cultures and times, from ancient art to modern Internet memes.

For example, ideas of symmetry around a center play an important role in the Hindu architectural tradition of *vāstu śāstra*, which is closely linked to ritual and originated with the design of altars and temples (Chakrabarti 2013: 2). Both the temporary structures built for rituals like those described in Section 5.1.3, and permanent temples and other buildings, show striking mirror and radial symmetry (Meister 1983). Examples can be seen in Figure 5.9 and 5.10.

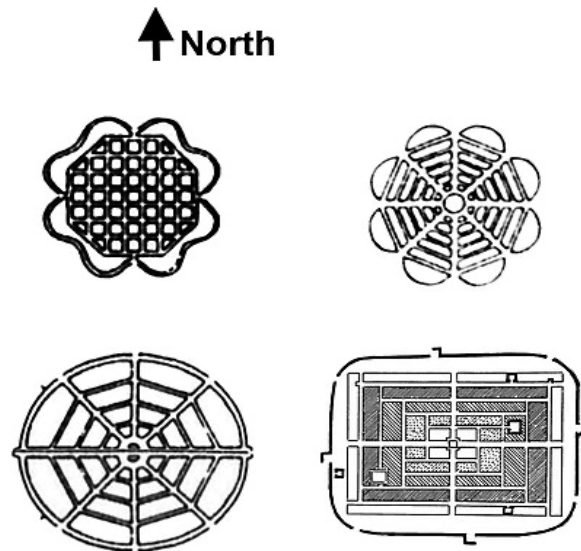


Figure 5.9: Radial symmetric town plans from the *Manasara*, a treatise on Hindu *vāstu śāstra* architecture from c. 700 CE. Image in public domain, from https://commons.wikimedia.org/wiki/File:700_CE_Manasara_Sanskrit_text,_Hindu_architecture,_town_village_plans.jpg

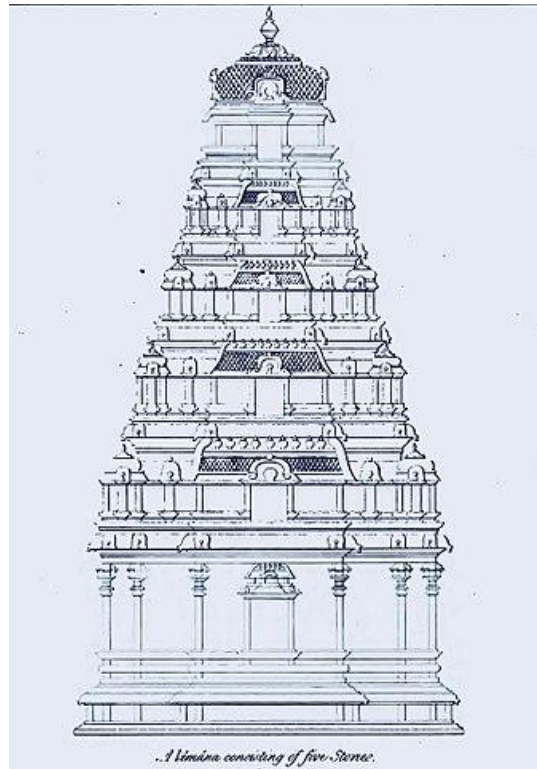


Figure 5.10: Illustration of Hindu temple showing bilateral symmetry, from Raz (1834).

As Niles (1973) reveals in comparing the *Song of Roland* to a Romanesque cathedral, there are parallels between visual artistic symmetry, which occurs widely in artistic traditions, and the symmetries of literary ring constructions. In the same vein, classical scholars have long observed similarities between the use of ring compositions in Homer, and the Geometric style of art which flourished around the 8th century BCE when the Homeric poems were likely composed (Whitman 1965: 97). Geometric designs made use of framed images, mirror symmetry and “bracketed” linear strings (A-B-A, A-B-C-B-A, and so on) of visual motifs, as in this schematic description (18) from Mackay et al. (1999) of a band design on a vase. The arrows indicate which way each figure is facing; the chariot appears in front view as the focus of the composition:

18.

Lion + Siren + Man + Chariot + Man + Siren + Panther

→ → → ^^^ ← ← ←

Symmetrical motifs of this sort are ubiquitous in decoration and architecture worldwide (see e.g. Weyl 1952, Eglash 1999, Darvas 2007). Wright (2016: 49) observes that the ABA and ABACABA structures of classical music have their counterparts in European architecture; for example, the main entrance (C) of a castle may be framed off by two groups of two towers with another structure between them (the ABA), as shown in Figure 5.11.



Figure 5.11: Château de Chambord, France, displays an ABACABA symmetry pattern. (Photo by Benh Lieu Song, from Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Chambord_Castle_Northwest_facade.jpg)

Decorative center-embedded strings continue to appear in modern-day Internet popular culture. Palindromic strings of emoji, punctuation, or other special characters may be used around a username, or bracket words to convey emphasis or tone, as in (19) from McCulloch (2020: 127):

19.

~~~~~\*\*\*\*\*~~~~~ so many sparkles ~~~~~\*\*\*\*\*~~~~~

(19) additionally fits the ABACABA pattern that appears in music – not only do the framing strings mirror each other, but each string of tildes and asterisks is itself a palindrome( $\sim^6/*^5/\sim^6$ ). More examples of emoji palindromes and brackets, of my own and my colleagues’ observation, appear in Figure 5.12. As these examples demonstrate, such strings of emoji can stand on their own, or appear as “frames” for a username, post title, or other bit of text being emphasized. They exemplify such forms as A-B-A, A-B-C-B-A, and longer palindromes. More examples, with source links or screenshots, are collected in Appendix C. (For an experimental look at the elicitation and learnability of palindromic and other embedded strings in nonlinguistic strings of icons, see Chapter 3.)

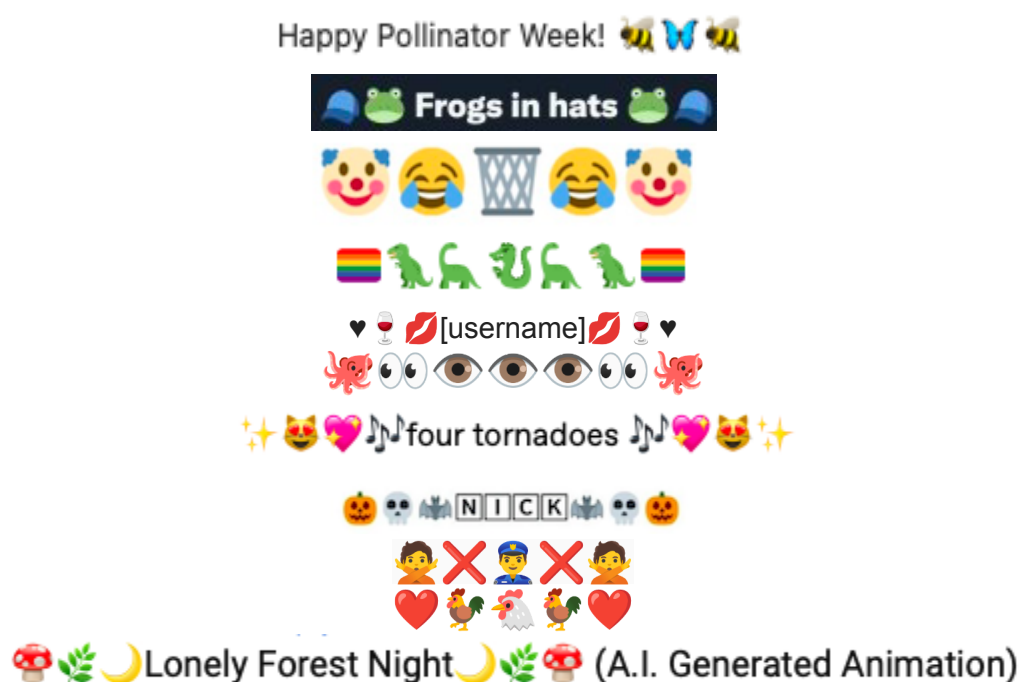


Figure 5.12: Some center-embedded emoji strings

Interestingly (especially in light of Staal’s observations of ritual “bracketing”), such nested emoji sequences also play a role in contemporary occultism, in the form of “emoji spells.” In this practice of Tumblr and Twitter neo-pagan communities, a string of emoji representing the caster’s intention is bracketed on either side by the crystal ball emoji (Towers 2015), or the

whole string of emoji may be palindromic. Duca (2016) quotes an emoji spell intended to “take down Donald Trump” where the name of the curse target is framed off by four emoji; this is reproduced in Figure 5.13.



Figure 5.13: A center-embedded emoji spell, from Duca (2016).

A broader treatment of symmetrical “A-B-A” patterns in visual art, and their aesthetic or symbolic values, would be beyond the scope of this discussion, but I note them here to emphasize the parallels to center-embedding in other art forms. Since these designs are laid out in space rather than expressed temporally, and lack semantic meaning (although emojis and other images can carry iconic meaning), they may permit a greater depth of embedding than sentences. The extent of center-embedding in visual media is limited only by practical considerations of space, money, and/or resources, and as seen in the above examples, emoji sequences can feature three or four sets of “brackets”. I now move from the world of art and return to more utilitarian and everyday activities, in which common tasks may feature surprisingly deep center-embedding.

#### 5.1.7. Complex task planning and everyday routines

Nonlinguistic center-embedding is not limited to ancient ritual and art forms, but arguably appears in our daily lives – not only in discourse (section 5.1.1) but in nonlinguistic actions. Pulvermüller (2014) describes center-embedded sequences in everyday, informal, and contemporary activities. (His observation was apparently independent of Staal’s, which itself attests to the ubiquity of center-embedded activity.) Pulvermüller refers to this phenomenon as

“action syntax.” The quotidian action of toothbrushing, in his analysis, has ten layers of center-embedded action sequences, forming a structure much like the rituals described by Staal (Figure 5.14). Each center-embedded layer is “bracketed” by a starting action and a corresponding conclusive action, such as entering and leaving the bathroom, or taking out a toothbrush and putting it back in its holder.

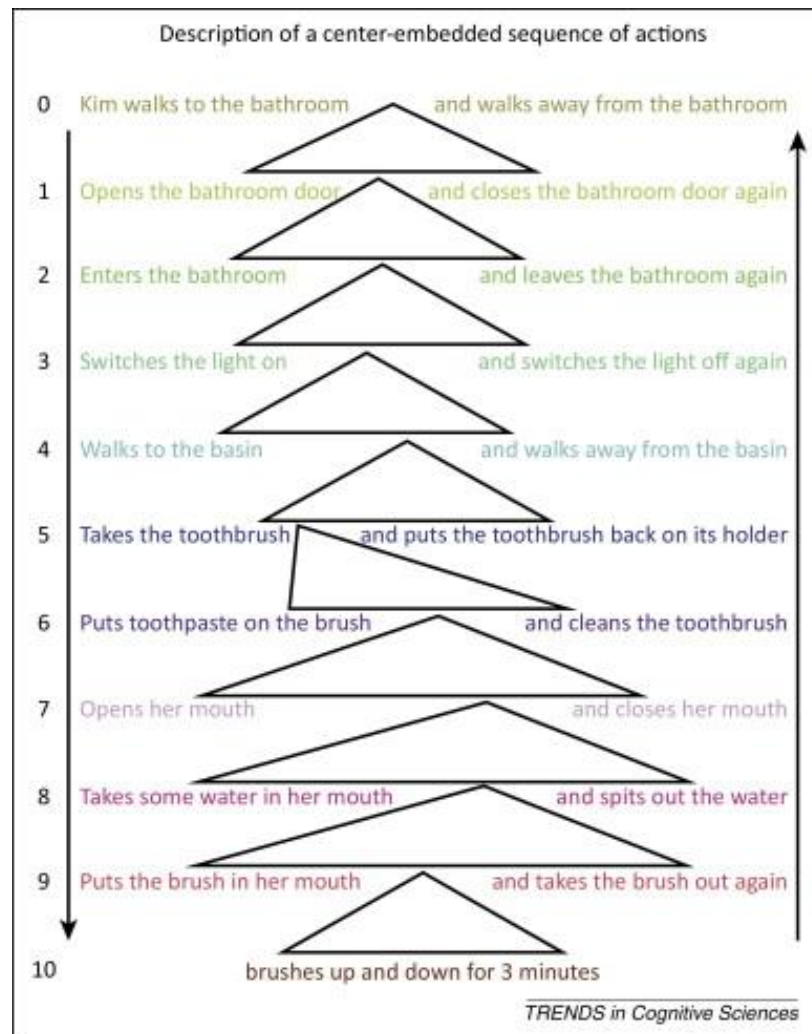


Figure 5.14: embedded structure of toothbrushing, from Pulvermüller (2014)

This observed similarity between syntax and action, along with the greater depth possible in action sequences, suggests an evolutionary and cognitive link between these faculties. Pulvermüller (2014) compares these complementary action pairs to dependencies



between words such as *either... or*. In both language and action, as previously noted, these dependencies can be nested – and in action the possible depth is far greater, possibly unlimited.

There are two major factors that constrain the depth and prevalence of multiple center-embedding at the sentence level: time and semantics. As observed in Chapters 1 and 2, natural languages rarely tolerate more than three center-embedded clauses or subject-verb dependencies, even when facilitating factors such as indexical embedded clause subjects are present. Staal's observation on linguistic and ritual time frames (Section 5.1.4) also applies to everyday activities, as it does to multi-person discourse, music, and literary structure (see Section 5.1.1 above, and Levinson 2013). While discourse and epic poetry do feature semantic meaning, they unfold over a greater time span than individual sentences, and thus are not subject to the time constraints of syntactic center-embedding.

Similarly, the action sequences involved in music and ritual may permit more center-embedding because they are not subject to either time or semantic constraints. That is, not only do they unfold over a longer time scale than spontaneous language, but also these sequences lack the semantic information that makes center-embedded sentences hard to process (see Chapter 1 and 2, and especially sections 1.2.2 and 2.3.2 for experimental and corpus evidence on how semantically “lighter” clauses aid processing). Semantic meaning presents more information to hold in memory while planning a sentence (exacerbating the challenges of processing on a shorter time scale) and can introduce ambiguity. In contrast, sequences of actions have no meaning of their own, and therefore cannot present any ambiguity; furthermore, every step plays a necessary role in the overall process, the goal of which may not be achieved if steps are skipped or taken out of order.

In a response to Pulvermüller (2014), Moro (2014) raises the possibility that planning may be ‘parasitic’ on language – i.e., recursively structured language is required to plan complex action sequences, rather than language having been exapted from action planning. Similar considerations would apply to the rituals described by Staal, as well as narratives –

certainly epic poetry requires language. I will return to this question of primacy in the conclusion (5.1.8.).

Therefore, on this account, it is plausible that center-embedding (and hierarchical structure more generally) in language is an exaptation from general action planning in both formal ritualized context and informal conventional activities, appropriately reduced in depth to compensate for the time pressure and semantic information that language possesses.

#### **5.1.8. A conclusion and transition**

In summary, center-embedding is not only present in the syntax of individual sentences, or in language, but appears in a wide range of human behaviors and artifacts. Starting with language, center-embedding occurs in multi-person discourse, in the form of nested adjacency pairs (e.g. question and answer). Center-embedded structures of various forms also occur in literature, such as nested narratives and poetic rhyme and meter. The ancient origins of these literary forms lead us to a possible point of origin for center-embedding: complex rituals where one rite is nested inside another, or “bracketed off” by multiple pairs of matched actions. Not only is center-embedding manifest in ritual activity itself, but analogous forms appear in domains of art associated with ritual, such as narratives and symmetrical art/architecture. As discussed in the previous sections, there is historical evidence for a link between the embedded structure of rituals and the earliest known embedded narratives (1.2-3), and symmetrical buildings such as altars and temples are also important to ritual practice (Section 1.5, see also Chakrabarti 2013). In the arts, center-embedded structures also appear in both sequential form in music, and static form in a wide range of visual arts, ranging in scale from the architecture of cathedrals to the use of emojis online. Finally, even everyday tasks such as tooth-brushing can be analyzed as consisting of center-embedded action sequences. In these nonlinguistic domains, center-embedding may attain depths greater than those observed in natural language, in which

sentences with more than two center-embedded clauses are generally hard to process and rarely observed in natural language.

Bringing together all of these observations from varied fields on the breadth and depth of nonlinguistic center-embedding, we have a possible evolutionary account for the origin of linguistic recursion: it is an *exaptation* (Gould & Vrba 1982) from cognitive faculties used for planning group and individual tasks. In addition, center-embedding is shallower and more restricted in language than in nonlinguistic behaviors, or even two-person discourse, because of the temporal and semantic constraints mentioned earlier: the “bottleneck” of spontaneous speech (which is not present in long memorized narratives such as epic poetry) and the constraints it places on working memory, and the additional processing difficulties introduced by semantics (which are not present in nonsemantic sequences such as music). Because of the time and semantic constraints, center-embedding in language is apparently limited to three embedded clauses, even with the aid of facilitating factors that reduce memory load. However, the depth of complex action sequences may be effectively unlimited, as demonstrated by Pulvermüller (2014).

While the range of center-embedding in nonlinguistic domains of human behavior is striking, it raises a “chicken and egg” question as noted by Moro (2014): do these observations really support the contention that recursion is prelinguistic? To fully answer the question of whether recursion is a prelinguistic feature, it is necessary to look outside our own species. Some (albeit tentative) evidence against the necessity of language for center-embedding in action and cognition comes from animal studies. Observations of possibly center-embedded patterns in animal ritual behavior and vocalization, and the ability of some animals to learn center-embedded patterns in laboratory experiments, suggest that a basic ability for center-embedding is present in at least some “advanced” warm-blooded vertebrates (i.e. mammals and birds). I will explore these observations and experiments in the following section.

## **5.2. Center-embedding and other dependency structures in animal behavior and cognition**

Further evidence for the prelinguistic nature of center-embedding comes from animal behavior and cognition. There is general evidence for long-distance dependencies and hierarchical structuring in a range of animal and human behaviors, including bird and whale song (Kello et al. 2017, Sainburg et al. 2019), human activities such as cooking, and animal motor behavior (Fitch et al. 2014, Sainburg et al. 2020); some examples from a variety of human activities were discussed in the previous section (5.1.). A variety of animal species, especially songbirds and primates, either naturally perform behaviors that can be analyzed as having a center-embedded structure or demonstrate the ability, in experiments, to recognize center-embedded patterns. In many cases, the patterns performed by animals display the simplest A-B-A form of center-embedding (e.g. a sequence beginning and ending with matched elements), and deeper-level patterns are not clearly attested. However, experimental studies suggest that some species of primates and songbirds are capable of comprehending more complex palindromic or bracketed patterns, and generalizing these patterns in ways that plausibly demonstrate mastery of appropriate abstract rules.

### **5.2.1. Naturally occurring behaviors**

Recursive syntax, of which center-embedding is a special case, may be rooted in nonlinguistic behaviors and cognitive abilities. As discussed in the previous section, center-embedded structures appear in human nonlinguistic activities; we now turn to similar observations among animals. In their foundational paper, Hauser, Chomsky, & Fitch (2002) made the strong claims that recursion is the essential characteristic of the human language faculty, and that it is unique to the language faculty and to humans – though they briefly suggest the possibility of a prelinguistic origin in abilities such as navigation, social cognition, and numerical ability (2002: 1571). Further, albeit tentative, evidence for the notion of a prelinguistic

and prehuman origin for recursive cognition comes from a few observations of animal rituals in the wild, which show an embedded structure like those of the human activities previously discussed in Section 5.1.4 and 5.1.7 – specifically, a significant action such as a greeting may be “bracketed” off by other distinct gestures.

### **5.2.1.1. Performances and constructions: birds and primates**

#### **5.2.1.1.1. Birds: dances and bowers**

Complex courtship rituals featuring “bracketed” structures are seen in some species of waterbirds. Staal (1980:137) suggests that animal ritual behaviors may show syntactic structure. He elaborates upon this notion in Staal (1984a:410), drawing on Huxley (1914): the courtship dances of great crested grebes (*Podiceps cristatus*), which Staal incorrectly calls penguins, show “regularities that reflect fixed rules.” The birds shake their heads, then dive, pick up water-weed, present it to each other, drop it, and shake their heads again (Huxley 1914:26ff). While Staal does not explicitly describe this ritual as showing embedding, his description of the sequence of actions could be analyzed as such: the head-shaking forms a “bracket” for the action sequence of picking up water-weed, presenting it to each other, and then dropping the water-weed again.

Center-embedded symmetry may also occur in constructions made by avians for courtship. As discussed in Section 5.1.6 above, center-embedding appears in a wide range of human visual art forms, ranging in scale from temples and cathedrals to modern-day online emoji art. There is some tentative evidence from the animal kingdom that this form of symmetrical construction may not be limited to humans – once again from the highly elaborate courtship behaviors of birds. Bowerbirds (family Ptilonorhynchidae) are a family of passerines in which males construct stages or “bowers” out of sticks, leaves, and other material, where they perform their courtship dances and songs for the females. They are arguably the only group of nonhuman animals that produce visual art. Examples of bowers from several species are shown

in Figure 5.15. For example, the Satin, Spotted, and Great Bowerbirds create bowers consisting of two arched walls of sticks surrounding a central “avenue” of ornamental material, showing a simple A-B-A pattern, reminiscent of the ubiquitous bilateral symmetry in many human art forms.

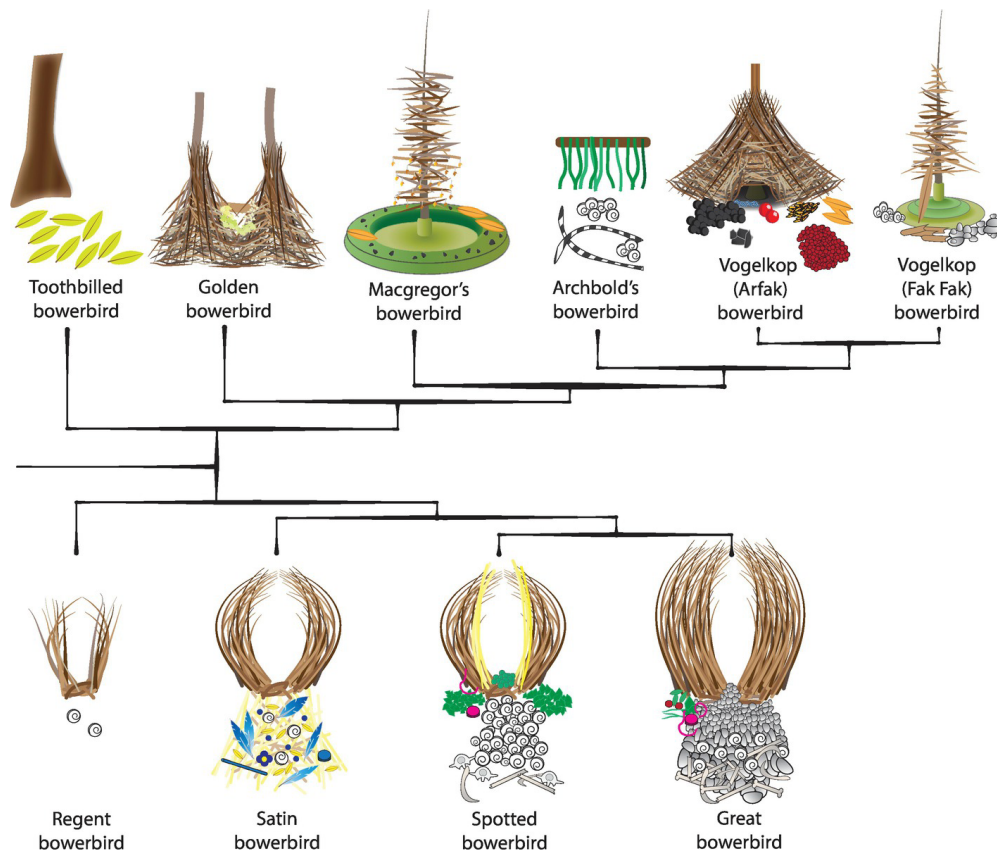


Figure 5.15: Illustrations of bowers constructed by a selection of bowerbird species. Note the bilateral symmetry evident in several, particularly the bottom row. From Keagy (2021).

#### 5.2.1.1.2. Primates: baboon greeting rituals

Greeting rituals between male baboons of the species *Papio cynocephalus anubis* (Smuts & Watanabe 1990:152) can also be analyzed to have a palindromic structure. In an encounter between males, one baboon approaches another with a distinct swinging gait and smacks his lips while making a distinctive facial expression (narrowed eyes, ears folded). If the other reciprocates the lips-smacking gesture and expression, the first male approaches closer

and performs the greeting (in which he mounts the second or touches his genitals), and then retreats with the same distinctive gait. Again, as in other embedded action sequences, the matched gait involved in approach and retreat “brackets off” the central action of the greeting, forming an ABA structure.

Both the baboons’ greeting gait and the grebe’s head-shake, serving to “bracket off” ritual actions and creating an A-B-A structure, resemble the matched beginning and end rituals described by Staal (1980:133). It is interesting to note that the ritual activity resembles a form of normal functional activity – mating, nest material collecting – but is marked off as ritual by the “bracket” actions. Furthermore, this activity performed in a ritual context does not fulfill the usual function of these activities, serving instead to create or maintain social bonding. These observations fit with the shared features of human and animal ritual described by Tonna et al. (2019): in ritual, the participants focus on the formal correctness of their actions (Staal 1979: 3), rather than the original functional goal of the behavior.

However, while intriguing, these accounts of palindromic behaviors are isolated and it is not clear if comparable behaviors are widespread across other species, or if they are always formalized within the species in question. The constructs of the bowerbirds, however, do appear to consistently exemplify bilateral symmetry, possibly indicating a convergence in cognition and aesthetic sense between distantly related species (humans are primate mammals, and birds are theropod dinosaurs). I now turn to another domain in which humans and avians show convergent evolution with regard to structure: songs and vocalizations.

#### **5.2.1.2. Complex vocal performances**

Some structures that are observed in animal calls and songs may exhibit structures comparable to the syntax of human language, including center-embedding. Birdsong, in particular, is often considered a possible evolutionary analogue to human language. While avian song does not show center-embedding, it does feature various types of dependencies and

hierarchical structures. Clear evidence for center-embedding (and other dependency structures) in animal vocalizations is uncommon, but some plausible examples have been found in passerine birds and monkeys.

#### **5.2.1.2.1. Birds: dependencies in song**

The song of oscine birds (songbirds) shows some evidence of hierarchical structure (Kello et al. 2017) and long-distance dependencies (Sainburg et al. 2019), including instances of crossed dependencies (Searcy et al. 2022). Birdsong is a plausible evolutionary analog to human language or a precursor thereof – significantly, it also shares general structural characteristics with music, an art form related to language in ways discussed in Section 5.1.5 above (see also Lehrdal & Jackendoff 1996, Jackendoff 2009). Birdsong also has language-like generative power: some songbird species can generate many song types (sometimes over a thousand) by rearranging discrete song elements (Yip 2013: 181).

Though it is lacking in compositional semantic meaning<sup>6</sup> and asymmetric syntactic structure (Berwick et al. 2011), birdsong does have a hierarchical structure broadly similar to the phonological hierarchical structure of human language. An avian song<sup>7</sup> can be divided into recurring elements known as “motifs,” which in turn are composed of “syllables”. Syllables are defined in a birdsong context as “acoustic productions separated by gaps of silence” (Yip 2013: 190). Finally, syllables can be further divided into time-frequency traces termed “notes.”<sup>8</sup>

Dependencies can occur between units at various levels, e.g. between syllables within songs or

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<sup>6</sup> Birdsong could be described as possessing a “holistic” meaning, as it conveys desire to mate or territorial claims, but it does not have compositional meaning (so far as is known).

<sup>7</sup> This is also termed a “song bout,” although Searcy et al. (2022), summarized below (Section 5.2.1.2.1.2), use the term “bout” for a string of identical songs.

<sup>8</sup> Birds are not the only animals that sing complex songs. Male mice also sing to attract mates, though their vocalizations are not quite as elaborate and flexible as those of birds (Chabout et al. 2015, Arriaga et al. 2012). Staal (1984a: 421, 1985) notes that human language and music, birdsong, and whale song all show broadly similar hierarchical structures at different time scales, an observation confirmed by later, more quantitative research. The songs of whales are less well studied – cetaceans being harder to keep in a lab than passerines or rodents – but there is evidence that they share general structural features with both birdsong and human music (Cholewak et al. 2013, Kello et al. 2017, Allen et al. 2019).



entire songs in a longer performance. An example of this hierarchical structure is shown in Figure 5.16.

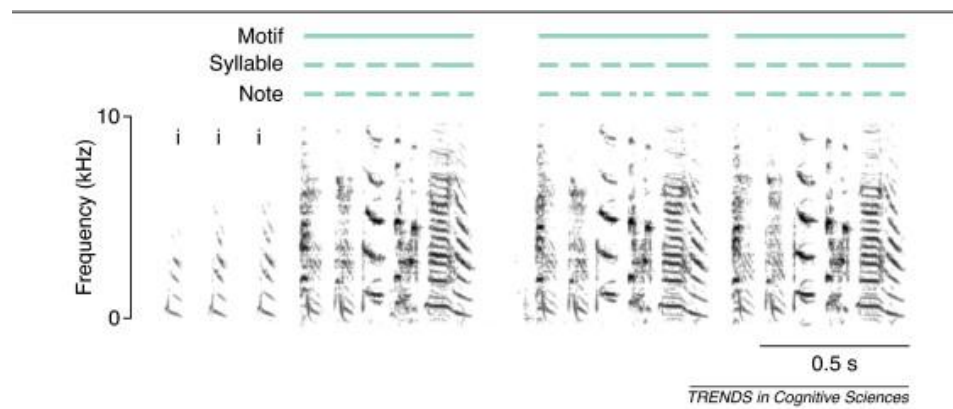


Figure 5.16: Hierarchical structure in the song of a zebra finch, from Berwick et al. (2011).

Additional evidence for structural similarities between birdsong and language comes from information-theoretic analyses. Sainburg et al. (2019) compared long-distance hierarchical structure in birdsong (of several passerine species) and human speech, by modeling the decay of mutual information between elements – i.e. the probability that one element will be present given the observation of the other. In human language, mutual information between words drops off with dependency length following a power law, which reflects the underlying hierarchical structure of language. The songs of several passerine species (starlings, Bengalese finches, Cassin’s vireos, and California thrashers) display mutual information trends similar to those observed in human speech, providing evidence that birdsong also has a hierarchical structure featuring long-distance dependencies.

Whether any structure directly comparable to linguistic center-embedding (or palindromic patterns like those in music) exists in birdsong is uncertain, but dependencies in general have been observed. I will elaborate on some observed cases in the immediately following subsections.

### 3.2.1.2.2.1. Long-distance dependencies in birdsong and the question of embedding

There is observed evidence for long-distance dependency structure in bird song, if not specifically center-embedding. Markowitz et al. (2013) demonstrated the existence of probabilistic long-distance dependencies in the song of domestic canaries (*Serinus canaria domestica*, Belgian Waterslager breed): the probability of a particular syllable occurring at one point in the song may be dependent on the appearance of another element separated by several syllables. For example, if a particular bird sings the syllable sequence T-B-D, the syllable K is the most likely to follow, but if the initial syllable in the sequence is U rather than T (producing the sequence U-B-D), then syllable J is most likely. Therefore, T-K and U-J form matched dependency pairs separated by intervening material.

The question of whether birdsong has recursive center-embedding beyond this basic A-B-A level has been explored, but is not yet satisfactorily resolved. With regard to the possibility of center-embedding, there are two theoretical possibilities for center-embedded birdsong structures: nested long-distance dependencies, and motifs that are interrupted (by another motif) and then completed. However, it is not known whether birdsong dependencies of the type documented by Markowitz et al. (2013) and Sainburg et al. (2019) can be embedded in other dependencies, as they are in human language. Similarly, there is no evidence that interrupted motifs actually occur; such a pattern, shown in Figure 5.17, has never been observed (Reuland 2013: 225). In this hypothetical example, motif M1 is split into two segments by an intervening motif M2 which is itself split by M3.

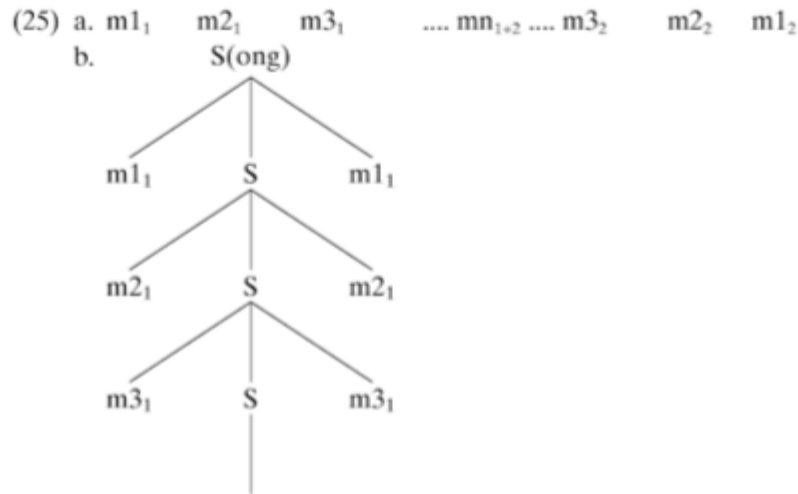


Figure 5.17: hypothetical embedded birdsong motifs (from Reuland 2013:225)

In summary, the existence of long-distance (probabilistic) dependencies in birdsong is confirmed, but there is as yet no evidence for more complex center-embedded patterns in birdsong comparable to those in human language or action sequence. However, absence of evidence does not entail nonexistence. We now turn to evidence for a different type of complex dependency pattern in the songs of a passerine bird.

#### 5.2.1.2.2.2. Other types of multiple long-distance dependencies in birdsong

While there is no clear evidence for multiple center-embedded dependencies in birdsong, other types of dependencies may occur – namely the crossed dependencies that are so atypical in human language (see the Introduction and Chapter 4). Searcy et al. (2022) described observations of long-distance dependencies in long (~30 minutes) performances by song sparrows (*Melospiza melodia*). Each of these long vocal performances consists of multiple bouts, each of which in turn consists of a song repeated several times. The overall structure of these performances follows several rules:

- Eventual variety: the bird repeats a song multiple times before switching to another.
- Cycling: the bird cycles through its repertoire in close to the minimum number of bouts; i.e. bouts of the same song occur at a minimum distance apart. This means that the

recurrence intervals between songs of the same type are shorter than those found in random sequences.

- Bout length: the longer a bout, the longer the interval (number of bouts) before that song occurs again.

These parameters, namely the order of song types in a sequence of bouts and the number of repetitions per song type, show long-distance dependencies between bouts: the more times a song is repeated, the longer the interval before it recurs again. The bout length rule therefore results in crossed dependencies that become apparent when the timeline of a song sequence is charted. These dependencies are at least six bouts in length, and can range as long as twelve bouts. Figure 5.18 shows an example of the resultant dependencies.



Figure 5.18: long-distance dependencies between bouts of song sparrow song as described in Searcy et al. (2022). Letters represent song types; numbers are how many times each song is repeated. Crossed dependencies are explicitly indicated by colored lines.

These findings contrast strikingly with the weaker evidence for center-embedded patterns in birdsong and similar animal behavior.<sup>9</sup> In any case, Searcy et al. (2022), along with Sainburg et al. (2019), provide a useful foundation for subsequent work on birdsong dependencies.

<sup>9</sup> For discussion of comparable evidence concerning the status of crossed and center-embedded dependencies in human cognition, with regard to language processing and artificial language learning, see Chapter 4.

#### 5.2.1.2.2. Primates

While center-embedding in birdsong has not been observed, plausible simple examples exist in the vocalizations of two species of primates, albeit ones not closely related to humans: the common marmoset, a New World monkey, and the gibbon, a lesser ape.

Common marmosets (*Callithrix jacchus*) are highly vocal and produce a variety of calls. Analysis of calls from a captive population of marmosets (Bosshard et al. 2022) revealed evidence of a long-distance dependency in trigrams: if a trigram begins with a food call, it will always end with the same call, and the element in between can be a call of any type. Thus the food calls “bracket” the other call. This structure can be interpreted as an example of a simple A-B-A center-embedded pattern, the minimal case of center-embedding.

Inoue et al. (2020, 2022) observed evidence of embedded call structures in the northern gray gibbon (*Hylobates muelleri*). In the songs of this species, sequences of two calls, designated AB, may occur, and an additional sequence of calls that occurs independently, designated N, may be inserted between the two. This produces the structure A-N-B. Furthermore, the embedded element N may itself be an AB sequence, producing a string of the form A-AB-B (Inoue et al. 2022). Note that this structure resembles the hypothetical “interrupted motif” bird call pattern described by Reuland (2013), illustrated above in Figure 5.17.

Although these are isolated examples, they are nonetheless fairly clear cases of simple center-embedding, and as such a possible evolutionary predecessor to the same types of dependency patterns in human language. However, these observations of embedded vocal patterns are from New World monkeys and gibbons, not great apes, so it remains unclear whether they reflect shared evolutionary heritage or convergent evolution. No comparable vocalization structures have so far been observed in the great apes. On the other hand, as discussed in Section 5.2.2.3.2 below, chimpanzees do show the ability to learn to recognize or process center-embedded sequences in experimental settings.

#### **5.2.1.2.3. Conclusion: animal vocal center-embedding**

Generally, the evidence of center-embedding (and patterns of multiple long-distance dependencies in general) from animal ritual, including avian song, is sparse, and the interpretation of these observed behaviors is not always clear. The primate vocalizations discussed above may be the clearest cases of simple center-embedding (A-B-A patterns, or dependencies with an intervening element) in animal calls.

However, some stronger evidence for the prelinguistic roots of center-embedding comes from experiments where animals learned to recognize or create different types of center-embedded structure. These observations suggest that center-embedding, even if it does not manifest in ordinary behavior, may be part of the cognitive toolkit of some nonhuman primates and other species (particularly birds and possibly also rodents). I now turn to the experimental findings.

#### **5.2.2. Learned behaviors: recognition and production of center-embedding in experiments**

A variety of experiments have tested the ability of passerine birds (starlings, finches, crows), nonhuman primates (monkeys, baboons, apes), and rodents (rats) to learn recursive patterns in nonlinguistic sequences. In this section, I consider experiments with several different types of sequences considered to instantiate center-embedding, from simple to more complex:  $A_n B_n$  sequences (e.g. AB, AABB, etc), sequences with a single long-distance dependency (resembling the simple A-B-A pattern of some natural animal rituals), and sequences with multiple long-distance dependencies (e.g. A B C B A, or a set of matched brackets like { [ < > ] } ). In nonlinguistic sequences of this type, as discussed in the introduction to this chapter, a dependency may take the form of identity or similarity between two elements in a sequence, or a pair of elements that consistently co-occur (i.e. a trained association).

### 5.2.2.1: $A^nB^n$ sequences

One simple form of sequence that can be analyzed as center-embedded is  $A^nB^n$ , e.g. AB, AABB, AAABBB, and so on. In sequences of this form, one unit of the form AB (representing a pair of elements of two different categories) is embedded within another. As previously discussed, sequences of this type occur in gibbon calls (Inoue et al. 2020), and some foundational studies of animals' abilities to process center-embedding have employed sequences of this type as stimuli. Fitch and Hauser (2004), in a foundational experiment, found that humans but not cotton-top tamarin monkeys could learn to correctly identify these sequences, and later research (Gentner et al. 2006) found that songbirds could learn to distinguish  $A^nB^n$  from non-matching patterns. However, it is uncertain whether such sequences are most accurately analyzed as center-embedding, and therefore whether pattern recognition for these sequences actually requires a grasp of a center-embedded grammar.

#### 5.2.2.1.1. Primates: Fitch & Hauser (2004) tamarins

In an early experiment on human and animal abilities to process center-embedding patterns, Fitch & Hauser (2004) tested auditory pattern recognition abilities in humans and cotton-top tamarin monkeys. Their stimuli consisted of strings of nonsense syllables spoken by either a female (A) or male (B) voice, adhering to either a finite-state grammar  $(AB)^n$  or a context-free grammar  $A^nB^n$ . Over multiple daily sessions, the monkeys were familiarized with auditory strings following one of these grammars, and then tested using novel strings which either adhered to the pattern or did not. Those trained on the  $(AB)^n$  grammar learned to recognize the pattern, while those trained on the other grammar performed no better than chance. Humans who were given an equivalent task, however, quickly mastered both grammars after only minutes of listening.

### 3.2.2.1.2. Birds: Gentner et al. (2006), starlings

Gentner et al. (2006) found that some European starlings (*Sturnus vulgaris*), an avian species known for its complex songs and ability to mimic sounds, can learn to recognize center-embedded recursive strings of the sort that cotton-top tamarins did not (Fitch and Hauser 2004). These strings were composed of “rattle” and “warble” sounds similar to the birds’ own calls, of the form  $A^nB^n$  up to  $n = 4$  (i.e. AAAABBBB). Gentner et al. demonstrated through follow-up experiments that the starlings that were successful (4 of 11) were not simply learning to recognize sequences of the form  $A^*B^*$  (where the asterisks represent values that need not be identical), because their responses to such patterns were different from those to symmetrical  $A^nB^n$  strings. Additional experiments ruled out other alternative strategies, namely listening for A/B transitions or pairs of the same motif type. In a supplement to the paper, Gentner (2006) demonstrated that a finite-state grammar capable of generating all  $A^nB^n$  strings used in the experiments (and ruling out the ungrammatical ones) would require 13 rules, not all of which could be learned from training. Therefore, he argues, it is more parsimonious to postulate that the starlings learned a single center-embedding rule than an elaborate system of finite-state rules that were not all inferrable.

However, it is not certain whether a center-embedding grammar must be employed to explain Gentner’s results. In a rebuttal to Gentner et al. (2006), Corballis (2007) argued that the starlings may have been counting and matching, not truly parsing center-embedded strings by “binding” pairs of matched elements. Similarly, Rogers and Pullum (2011: 339) argued that a finite state grammar augmented with a counter (to test if the number of B elements matches that of A elements) is sufficient for recognizing sequences of form  $A^nB^n$  and excluding  $A^nB^m$  sequences. In this analysis, a center-embedding grammar is not necessary to explain the results. Therefore, it is questionable, on the basis of these results, whether songbirds are capable of learning center-embedded patterns.



We now turn to experiments involving the learnability of patterns that more clearly exemplify center-embedding rules, namely sequences with the sort of “bracket” or palindrome structure discussed previously in relation to human and animal activities. There is experimental evidence that songbirds, rodents, and primates are all capable of learning to recognize sequences with these patterns, at least at the simplest level.

#### **5.2.2.2: Single dependency sequences (A-B-A)**

The simplest type of sequence that unambiguously instantiates center-embedding is A-B-A, a minimal pattern consisting of two identical or matched segments preceding and following a different segment. As explored previously, this pattern is widespread in human music and narratives, and possibly occurs in some animal activities. The two A elements may be identical, matched in some way (e.g. musical sequences of the same key), or elements that are not perceptually similar but consistently co-occur.

##### **5.2.2.2.1. Birds**

###### **5.2.2.2.1.1. Abe and Watanabe (2011), Bengalese finches: experiment 1**

In a follow-up to Gentner et al. (2006), Abe and Watanabe (2011) performed a series of experiments on Bengalese finches (*Lonchura striata domestica*) to test the birds' ability to discriminate syntactic structures. The finches were familiarized with auditory sequences (composed of motifs from their own songs) which contained predictive long-distance dependencies; this was termed a predictive language. In a predictive language, if motif A appeared in a sequence, motif C would always follow (non-adjacently), whereas in a non-predictive language, a C could occur without a preceding A. Once habituated to these stimuli, the birds produced response calls to novel strings following the same grammatical

paradigm<sup>10</sup>, but called significantly less in reaction to ungrammatical strings, which the authors take as an indication that the birds had learned the dependency rule involved.<sup>11</sup>

#### **5.2.2.2.1.2. Chen and ten Cate (2017)**

Chen and ten Cate (2017) demonstrated that zebra finches are capable of learning a similar dependency-recognition task. In their stimuli, dependencies took the form of two elements that were always matched: A /B or C/D, with an intervening sequence of varying length. The birds were first trained on stimuli with the dependency elements adjacent, and later worked up to nonadjacent dependencies with a varying number of intervening elements. Some birds, though not all, learned to reliably distinguish grammatical phrases (those with a matched dependency pair) from ungrammatical (an incorrect pair such as A/D, or a dependency pair in the wrong order such as B/A), including generalization to new phrases following the same rules.

Taken together with Gentner (2006) and Abe & Watanabe (2011), these findings suggest that some form of dependency recognition may be common across songbirds, which is consistent with the previously discussed evidence for dependencies in naturally occurring birdsong (Markowitz et al. 2013, Sainburg et al. 2019; see Section 5.2.1.2.1 above for an overview).

#### **5.2.2.2.2. Rodents: Murphy et al. (2008)**

Most research concerning center-embedded and dependency patterns has involved either primates or songbirds, but there is also some evidence that rodents can learn these patterns. Murphy et al. (2008) successfully trained rats to associate A-B-A sequences of lights with food, and then found that they could generalize the pattern to new sequences, for example a B-A-B sequence, with the “roles” of the different lights reversed but the abstract pattern

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<sup>10</sup> Why the birds responded vocally to “familiar” stimuli but not unfamiliar stimuli is not certain, but the fact that they consistently showed a different response to strings of different categories confirms that they had learned and generalized the underlying rule.

<sup>11</sup> A follow-up study in the same paper, examining the birds’ ability to recognize more complex sequences, is summarized below in Section 5.2.3.1.

remaining the same. This indicated that the rats were recognizing an abstract pattern across different stimulus sequences, and differentiating a pattern where the first and last elements matched (A-B-A or B-A-B) from one with adjacent identical elements (e.g. A-A-B or A-B-B).

### **5.2.2.2.3 Primates**

There is also some evidence that great apes and monkeys can learn to recognize simple nonadjacent dependency patterns, in both visual and auditory sequences. In this section, I summarize two such experiments, one with chimpanzees on visual sequences, and one with marmosets using auditory stimuli.

#### **5.2.2.2.3.1. Sonnweber et al. (2015): chimpanzees and visual sequences**

Sonnweber et al. (2015) trained chimpanzees to recognize visual sequences that began and ended with items that were visually similar (e.g. the same shape) or a pair of distinct shapes that the chimps had previously been trained to associate. These strings thus exemplified long-distance dependencies with or without a perceptual similarity. Examples of the training stimuli and the types of test stimuli used, with visually similar dependencies, are illustrated in Figure 5.19; S+ indicates strings following the dependency rule and S- indicates strings that did not follow the rule. The chimp participants learned to recognize dependencies of both types and generalize to new stimuli following the same pattern, but differing from the training stimuli along several parameters: e.g., the color of the symbols (1 in Figure 5.19), the length of the sequence (2), or the inclusion of novel shapes (3). Some but not all subjects also learned to distinguish sequences in which the dependency constituted the first and last elements (ABCA) from those in which one element of the dependency pair was duplicated (AABCA, 4 in Figure 5.19), the pair appeared in positions other than the first and last (ABAC, 5), or an additional instance of the dependency element occurred in the middle (ABACA, 6). Finally, the chimps were tested on

sequences where the parameter that formed matching dependencies was color, not shape, and some (of those trained on arbitrary associated dependencies) also generalized to this new feature (7 in Figure 5.19), suggesting they had gained a competent understanding of the abstract concept of a dependency.

| Feature-Based Dependencies  |         |    |
|-----------------------------|---------|----|
|                             | S+      | S- |
| training:                   | A A<br> |    |
| testing:                    |         |    |
| 1. color:                   |         |    |
| 2. extension:               |         |    |
| 3. novel shapes:            |         |    |
| 4. duplication:             |         |    |
| 5. dependency position:     |         |    |
| 6. center near edges foils: |         |    |
| 7. category transfer:       |         |    |

Figure 5.19: Training and testing sequences with feature-based dependencies, from Sonnweber et al. (2015). S+ indicates strings following the dependency rule (A-B-A); in S- strings the dependency rule is violated in some way.

#### 5.2.2.2.3.2. Reber et al. (2018), marmosets and musical tones

Similar abilities have been demonstrated in primates less closely related to humans. Reber et al. (2018) tested the ability of marmosets (*Callithrix jacchus*) to recognize the presence or absence of a long-distance dependency in a sequence of tones. In this case, the dependency consisted of two identical elements at the start and end of the sequence. Marmosets were tested in a soundproof chamber in which they were habituated to tone sequences that began and ended with the same element. Then the test sequences were played. When the monkeys heard new sequences with the same pattern (i.e. one matching A-B-A), they looked toward the sound source more often than for sequences that did not follow the pattern. This looking

preference was taken to indicate pattern recognition, and the observed ability to generalize to new sequences indicates that the monkeys were accurately recognizing the dependency rule at hand rather than simply memorizing sequences.

These results on sequences with a single long-distance dependency, combined with the natural behaviors discussed above, suggest that the ability to recognize or generate simple A-B-A patterns and comprehend the abstract rule underlying them may be common across other “advanced” warm-blooded vertebrates, especially those capable of vocal learning (such as birds).<sup>12</sup> It is still something of an open question whether this ability entails the capacity to recognize more complex center-embedded patterns; I will address experiments concerning sequences of this type.

#### **5.2.2.3. More complex sequences: brackets and palindromes**

In the preceding section (5.2.2.2) I have summarized research concerning A-B-A patterns with a single dependency, the simplest unambiguous form of center-embedding. However, there is also evidence that nonhuman animals can deal with more complex center-embedding patterns, more akin to those found in human language and the range of activities discussed in Section 5.1. These sequences include longer palindromes of the form ABCBA, or sequences of nested brackets such as { [ ] }, where the nested pairs of elements, from inner to outer, are related either perceptually (e.g. through color, shape, or sound) or through a learned association. Some species of birds and primates (great apes and Old World monkeys) have successfully been taught to recognize sequences of this form, using both auditory and visual paradigms.

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<sup>12</sup>Some rodents are also vocal learners, though in a more limited capacity than birds (see e.g. Arriaga & Jarvis 2013 on mice, and Barker et al. 2021 on naked mole rats). Rats (genus *Rattus*) are not thought to be vocal learners, but exhibit the ability to generalize prosodic patterns in human speech in a similar way to humans and vocal-learning avians (Toro & Hoeschele 2017). The exact relationship between vocal learning and learning of sequential patterns remains to be fully explored.

#### 5.2.2.3.1. Auditory sequences: Abe and Watanabe (2011), Bengalese finches: Experiment 2

Some experimental evidence suggests that songbirds can learn to recognize the pattern of center-embedded sequences with nested pairs of brackets, as well as the simple A-B-A paradigm of a single dependency, although the evidence is not entirely clear. In a follow-up to their experiment discussed in the above section, Abe & Watanabe (2011) trained Bengalese finches (*Lonchura striata* var. *domestica*)<sup>13</sup> on sequences with and without a center-embedded structure, again using response calls as a measure to test comprehension. Center-embedding was defined as the presence of up to three nested pairs of matched segments; an example of a sequence would be ABCBA, where A's and B's represent matched pairs of syllables taken from the finches' songs, and C is a variable central syllable. The finches learned to generalize the center-embedding rule: they called in response to strings following this rule, including novel strings, but not those violating the pattern. The finches even generalized to higher-order center-embedded strings, i.e. from two levels of embedding to three, which suggests a high-level grasp of the general abstract pattern involved.

As with the previous work on starlings (Gentner et al. 2006), Abe & Watanabe's conclusions about the grammatical abilities of songbirds have been criticized. Beckers et al. (2012) argue that there is no need to propose that the finches actually learned a center-embedding rule. They note that the number of embedded and non-embedded strings used in training was very small, and that longer grammatical embedded strings all contained shorter (already familiar) grammatical embedded strings as substrings, e.g, the birds were familiarized on string ABCBA and then received DABCBAD as a test string. This means the

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<sup>13</sup> This subspecies is also called the society finch. As the taxonomic name suggests, it is a domesticated variety of the white-rumped munia, *Lonchura striata*. Kazuo Okanoya (personal communication) insists that Bengalese finches have a different domestication and breeding history from society finches, even though both belong to the same species designation, *Lonchura striata domestica*. It is true that domesticated Bengalese finches were first imported into Europe from Japan in the mid-19th century, whereas Okanoya (2012) pinpoints the mid-18th century as the starting point for the domestication of the species in Japan. It is also true that the bird is referred to as a society finch in North American but as a Bengalese finch elsewhere.

finches could simply have memorized some of the shorter strings and listened for those strings, or for strings that differed only in the medial syllable (e.g. the familiarization string was ABCBA, and a test string was ABDBA). Therefore, it is not certain whether the birds must have necessarily learned a center-embedding context-free grammar, generalizing across string lengths, in order to produce the results attested.

However, the results of Abe & Watanabe's (2011) prior experiment, in which birds recognized long-distance dependencies, are robust and intriguing, since these single dependencies are a necessary precondition for deeper center-embedding patterns.

#### **5.2.2.3.2. Rey et al. (2012): baboons**

In addition to the simpler dependency structures discussed above, other experiments with non-human primates have used visual or auditory stimuli with more robust representations of center-embedding, such as palindromic sequences or those with matched pairs of “brackets”. However, the usual caveats still apply: the implications of the patterns produced are not entirely clear here either, as it is problematic to determine what the animal participants are doing cognitively, and if they are truly attentive to the center-embedded structure or to some other aspect of the sequence.

Rey et al. (2012), on the basis of experimental results, argued that baboons (*Papio papio*) have a preference for center-embedding grammars over non-embedding ones. In their experiment, the baboons were taught to sequentially press pairs of icons ( $\Delta$ ,  $\Phi$ ,  $\vartheta$ ,  $\Gamma$ ,  $\Sigma$ ,  $\Omega$ ,  $*$ ,  $\ni$ ,  $\varsigma$ ,  $\&$ ,  $\lambda$ ) on a series of computer screens. These twelve icons were categorized into six arbitrary pairs, henceforth notated A1/B1, A2/B2, et cetera, and the baboons were trained to select these particular pairs.

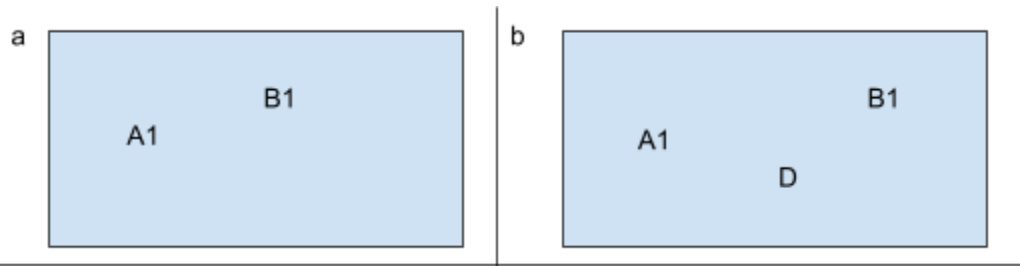


Figure 5.20: schematic of screens used for training baboons in Rey et al. (2012).

Figure 5.20a shows the first training phase, in which the baboons were required to press icons A1 and B1 in that order for a reward; 5.20b shows a second training phase, in which they had to select A1 and B1 and additionally avoid a distractor D (which did not constitute a member of any pair). This process trained the baboons to associate symbols in ordered pairs, e.g. A1 with B1 and A2 with B2, and after performing to criterion (80% correct in three 100-trial blocks) they moved onto the next phase. In subsequent training phases, the baboons were required to select the correct B icon for a given A (and avoid a distractor in the form of another B icon) in order to be rewarded – e.g. the screen would show A1, B1, and B2, and getting a reward would require touching A1 and then B1. Then, they were taught to match two A-B pairs in the following procedure: first the screen would display both A's with a distractor, and the baboon would be required to select both A's (in either order) and avoid the distractor. At this point the screen would display two B's and a distractor, and the baboon would again have to select both B's (in either order) and avoid the distractor; after completing the full AA BB sequence of this type it would be rewarded.

In the testing phase, the baboons first saw the screen depicted in Figure 5.21a, and were required to select A1 instead of a distractor (D) in order to advance to screen b. On this screen they were required to select A2 (again avoiding a distractor) in order to advance to either screen c or screen d. On this final screen, they had to pick B1 *and* B2, in either order, to be rewarded – avoiding either a third class-B segment (in c) or a distractor (in d). After the baboons had entered two segments on the final screen, the task ended, and they were rewarded only if both B1 and B2 had been selected (regardless of order).



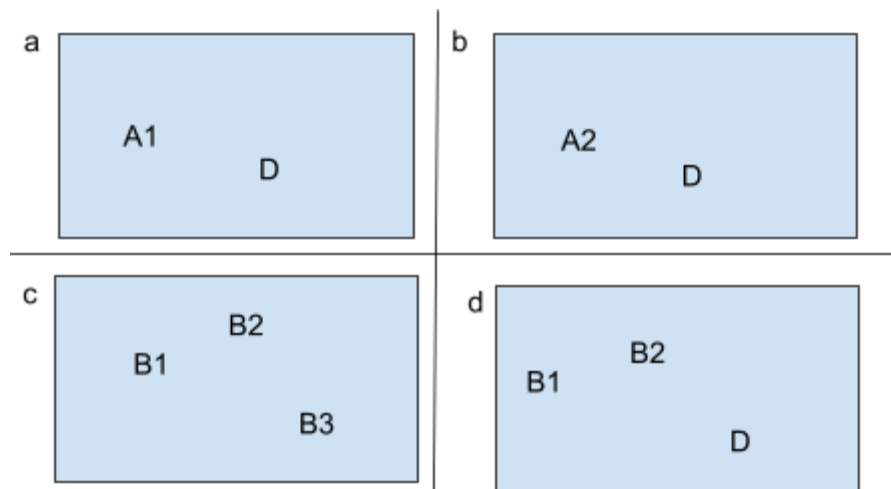


Figure 5.21: Schematic of testing screens in Rey et al. (2012).

The primates were not specifically trained to construct center-embedded sequences, only to pick the two B segments which they had been trained to match to the A's; i.e. if they had selected A1 and A2, they would be rewarded for selecting B1 and B2 in either order but not B3. However, they produced significantly more embedded sequences ( $A_1A_2B_2B_1$ ) than non-embedded or "crossed" sequences ( $A_1A_2B_1B_2$ ). The authors argue that this implies a preference for embedded structures, based on working memory constraints (the last-in-first-out stack), and that the prevalence of center-embedded dependencies in human language follows from these constraints. Crossed dependencies, on the other hand, are uncommon in language, reflecting the fact that they are less amenable to short-term memory under the assumption of a memory stack.

Poletiek et al. (2016), however, were skeptical as to whether the findings of Rey et al. (2012) are relevant to human syntax, or whether they demonstrate what the authors claimed about a preference for embedding. Poletiek et al. (2016) noted that, while the baboons preferred embedded to "crossed" patterns, they also picked the B distractor significantly more often than an option that matched either A: for example, after producing  $A_1A_2B_2$ , they picked  $B_3$  (which they had not been trained to associate with either of the given A's) significantly more than the correct  $B_1$ . In addition, there was no statistical dependence between the choice of a first B element and

the choice of a second; i.e., following the selection of the icons designated  $A_1$ - $A_2$ ,  $B_1$ - $B_2$  and  $B_2$ - $B_1$  did not occur at significantly different rates. This indicates that the baboons were not planning ahead to create an embedded sequence of the form  $A_1A_2B_2B_1$ . Poletiek et al. (2016) concluded that, to truly demonstrate the presence of center-embedded structure in animal behavior, it would be necessary to show that the animals can tally up the number of embedding “brackets” – an ability which was not tested in Rey et al. (2012), since the baboons were always rewarded after entering the two matching B icons, in either order, and could not create sequences of different lengths within the interface used.

#### **5.2.2.3.3. Jiang et al. (2018): Macaques**

Further experiments have addressed the center-embedding question more directly by using sequences that require animal or human subjects to generate either palindrome patterns or another type of pattern, e.g. repeat (crossed dependency) sequences. Jiang et al. (2018) trained two macaque monkeys (*Macaca mulatta*) on two grammar patterns: center-embedded “mirror” structures of the form ABCCBA, and repeated/crossed strings of the form ABCABC. These sequences were presented on a touch screen as dots appearing at the vertices of a hexagon. A sequence of three vertices (notated ABC) would light up sequentially, followed by a visual cue indicating which type of pattern had to be followed (e.g. a green dot for mirror sequences or a yellow dot for repeat). To attain a reward, the monkeys had to complete the whole sequence correctly by touching locations ABC again in the correct order – either forward or in reverse, according to the visual cue seen. Performance was significantly better than that expected by chance. The monkeys were then tested with sequences of length 4 (e.g. ABCD / DCBA), and with novel layouts (e.g. the dots were arranged in a pyramid shape, in a straight line, or at random points on the screen, rather than on vertices of a hexagon). In all cases they learned to complete sequences following the grammar corresponding to the cues. One monkey also learned to produce complete sequences from the first segment and the grammatical cue

alone: e.g. after viewing A + mirror cue, it entered the sequence BCCBA, while the other did not. However, it took the monkeys thousands of trials to reach about 60% accuracy on length-4 sequences. Conversely, human children tested on the same protocol learned the pattern within 5-10 trials, subsequently performed nearly at ceiling, and generalized instantly to new layouts.

#### 5.2.2.3.4. Malassis et al. (2020): baboons

There is further experimental evidence for a possible discrepancy in learnability between mirror and repeat sequences for nonhuman primates. Malassis et al. (2020) performed another test of baboons' ability to learn grammars following two patterns: center-embedded and crossed/repeat. The subjects were trained to tap out sequences on a touchscreen with an array of 16 points in a grid (Figure 5.22).

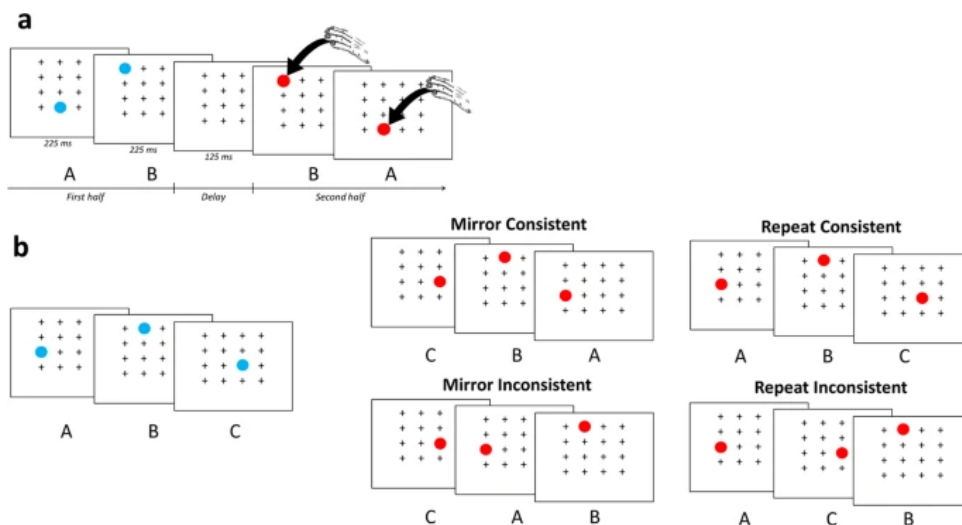


Figure 5.22: Experimental setup from Malassis et al. (2020). (Image licensed under <https://creativecommons.org/licenses/by/4.0/>)

Sequences were displayed by points lighting up. The first half of the sequence would be displayed, followed by a pause; then the second half would appear in the same way and the baboon would have to touch the target points for the second half of the sequence as fast as they appeared. (Correct performance was not differentially rewarded; rather, the baboons got a food reward after every trial regardless of exact performance.) Inference of the grammar was

measured by response time to grammatical sequences versus violation sequences in the second half. It was assumed that if the grammar had been learned, then reaction times would be faster for grammatical sequences than for sequences with violations (for example, a correct mirror sequence would be ABC CBA, and an incorrect one would be ABC BCA), because the baboons were anticipating the oncoming sequence. This prediction was borne out in mirror (center-embedded) sequences, and the baboons generalized to new sequences (i.e. those composed of new locations on the screen). However, there was no response time difference for repeat sequences, suggesting that patterns in these sequences were not recognized. Humans, unlike baboons, quickly learned both types of patterns.

#### 5.2.2.3.5. Ferrigno et al. (2020): macaques and humans

Additional evidence for a difference between human and nonhuman primate sequence learning, covering a more diverse group of humans, comes from Ferrigno et al. (2020). Their human participants were of different ages and cultures: children and adults from North America and adults from an indigenous Amazonian group, the Tsimane (who lacked training in reading and mathematics). The performance of the humans was compared to that of three monkeys (adult rhesus macaques) on the same task. These participants were trained to produce specific sequences of opening and closing brackets (e.g. { [ ] } ) by selecting the brackets on a touch screen, and were given positive feedback for producing a specific center-embedded sequence for each set. For example, a set with two curly parentheses { } and two squared brackets [ ] would require the order { [ ] }, and a combination of curly { } and round ( ) would require order { ( ) }.

Once trained on these two sequences, subjects were then given test trials with a novel combination of brackets: square [ ] and round ( ), and asked to generate sequences without differential feedback, to assess whether the center-embedding pattern was generalized or

whether the subjects were using a different strategy based on ordinal position or adjacency. The authors hypothesized that if the subjects were following an ordinal strategy, i.e. inferred rules for which types of bracket occurred at which points in the sequence, they would not consistently produce a center-embedded pattern, since both square and round brackets had only occurred in the middle positions of the four-bracket sequences they had learned, i.e. { ( ) } and { [ ] }. Instead, they would produce crossed structures like [ ( ] ) at the same rate as center-embeddings like [ ( ) ]. These crossed sequences satisfy the ordinal rule because they have an open bracket of either type at position 2 and a closed bracket of either type at position 3. On the other hand, if they were following an associative strategy (memorizing which brackets could be adjacent to each other), they would produce “tail-embedded” sequences with one pair of brackets after the other, i.e. [ ] ( ) or ( ) [ ] .

The results for test trials showed that human participants successfully generalized the center-embedded patterns, although monkeys did not make the same generalization. Human participants of all groups produced center-embedded sequences at above chance level, and more frequently than crossed sequences such as [ ( ] ), whereas only one of the three monkeys showed similar performance (another almost exclusively generated tail-embedded strings). However, the monkeys’ production of center-embedded sequences increased when they were given additional training trials using novel brackets (different colors and shapes); two of the three subjects showed performance similar to human children. There was also substantial variation between the monkeys’ individual performances after additional training: one actually generated center-embedded sequences more frequently than did some human participants, while another almost exclusively generated tail-embedding sequences like [ ] ( ) and never created center-embedded patterns. The authors take these results to support the notion that humans, particularly adults, tend to infer hierarchical structures in sequences (what Fitch (2014) terms “dendrophilia”). While monkeys were capable of learning center-embedded patterns, this

ability may not be widespread across the species, and requires more trials to be learned than in humans.

Like many of the previously discussed recursive sequence learning studies, Ferrigno et al. (2020) have been criticized for their interpretation of their results, and whether the latter truly exemplify learning of recursive rules. Lakretz and Dehaene (2020) suggested that recursive rules are not required to explain the monkeys' performance on the bracket task. Instead, they argue, the monkeys could have used a simple sequence-memory strategy, in which positions in a sequence are associated with filler items in memory, a process described by Botvinick & Watanabe (2007). Under this assumption, the monkeys would pick one open bracket for the first position (either of which could occur initially in trained sequences), then the leftover open bracket, followed by the two closed brackets in either order. This would result in about equal production of embedded and crossed sequences, which is what was observed in Experiment 1 (though not for all three monkeys). Moreover, the fact that the monkeys produced more embedded sequences after additional training can be accounted for by the systematic pairing of matched inner brackets, [ ] and ( ), in trained sequences.

In response to these criticisms, the authors (Ferrigno et al. 2020b) argued that Lakretz's model is not consistent with the types of errors produced by the monkeys, and does not account for their ability to generate center-embedded sequences with combinations of brackets not previously seen before. If the monkeys were combining brackets based on observed transitional probabilities, they would not generalize to new combinations, for which the transitional probability between brackets is zero or undefined. They also observed that "no matter what amount of training is provided, a critic could always construct an ad hoc architecture to process it, and claim that deeper nesting is required for 'true' recursion." This response is appropriate for many of the criticisms of animal recursion experiments discussed in this section. Another question that remains is whether it is more reasonable to assume that the animal has learned recursive rules, or used a nonrecursive process which is as complex as necessary to explain the

observed patterns of learning without recursion. The set of rules or strategies required to produce the recursive patterns without actual cognition of recursion could also place more of a burden on memory than a single recursive strategy.

#### 5.2.2.3.6 Visual sequences: Liao et al. (2022), corvids

Most experimental research involving pattern recognition in birds has employed auditory sequences, but there is also some intriguing evidence that songbirds, specifically the highly intelligent corvids, can learn to identify center-embedded patterns in visually displayed sequences. Liao et al. (2022), a followup to Ferrigno et al. (2020), successfully trained two crows to recognize these types of sequences with better performance than the monkeys in that study.

In Liao et al. (2022), two carrion crows (*Corvus corone*) were trained to peck brackets displayed at random positions on a screen in the order of a specific center-embedded sequence. The structure of a trial is shown in Figure 5.23. For example, a pair of curly brackets { } and a pair of square brackets [ ] would appear at random spatial positions on the screen (the closed brackets were additionally marked with a colored border, rendered here as gray highlighting), and the bird had to peck them in the order { [ ] } to be rewarded. In this way, the birds were trained on two different sets of two bracket pairs, curly/square { [ ] } and curly/round { ( ) }.

## A Task structure

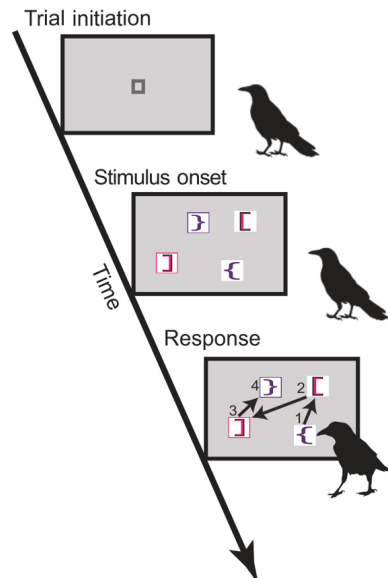


Figure 5.23: Structure of a trial in Liao et al. (2022). The bird was rewarded for pecking the brackets in a specific center-embedded sequence, i.e. { [ ] }

Once the crows had performed to criterion on these bracket sequences, they were given transfer trials to assess whether they were successfully generalizing the center-embedded structure. These transfer trials included bracket types not seen together during training, i.e. a pair each of square [ ] and round ( ) brackets. On these trials, the crows were rewarded for pecking the brackets in any order, rather than for generating a specific sequence. The crows produced center-embedded sequences, i.e. [ ( ) ] and ( [ ] ), at a rate higher than chance on transfer trials. Center-embedded sequences also occurred much more frequently in the birds' responses than other logically possible and equally probable bracket structures, namely crossed structures [ ( ) ] and ( [ ] ) and what the authors called tail-embedded structures: ( ) [ ] and [ ] ( ) . This preference for center-embedding indicates that the crows were not using a simple ordinal rule based on the occurrence of certain types of brackets at certain points in the string, e.g. that open brackets must occur in the first two positions, and closed brackets in the final slots. If they were following an ordinal rule, they would produce center-embedded and



crossed responses at an equal frequency. Nor were the crows simply tracking which brackets were adjacent in trained sequences. A strategy based on adjacency would be expected to produce predominantly tail-embedding responses, because both types of brackets in the transfer trials had appeared in training only as adjacent open-closed pairs: **[ ]** and **( )**.

A second experiment suggested that the crows were sensitive to the hierarchical ordering of “outer” and “inner” brackets. In this case, they were trained on two sets of brackets (angled/square or square/round) and required to produce a specific center-embedded order for each, shown in (20):

20.

< **[ ]** >  
**[ ( ) ]**

In transfer trials containing the angled < > and round brackets ( ), which had never occurred together in training, the crows produced the order < ( ) > in almost every trial, instead of the other logical possibility ( < > ). This suggests that the birds had inferred a hierarchical order never displayed in full: angular, square, round, an inference which could not be accounted for by simply memorizing sequences. While this response pattern could be explained with a template strategy (i.e. a rule that angled brackets must appear in the first and last position, and round brackets in the middle positions of the strings), the results of the third experiment effectively ruled out reliance on a strict template, as I will now discuss.

Finally, Liao et al. (2022) tested the crows’ ability to learn longer bracket sequences, and to rule out the possibility that their previous results were based on an ordinal strategy – e.g. a memorized template representing which brackets could occur at which positions in a sequence. Training sequences and task structure are shown in Figure 5.24.



Figure 5.24: Training sequences from Liao et al. (2022), Experiment 3.

Two types of transfer trials were used, swap and joint; examples of the bracket sets used in these trials are shown in Figure 5.25. The bracket sets used in swap trials were produced by combining pairs of brackets from the trained sequences while including one pair of brackets for each position within the string. For example, a swap trial could be generated by displaying the outer two bracket pairs of List 2 (blue angular and green square) together with the innermost pair (orange circular) from List 1. This produced a new set of brackets the crows had not seen together in training.

If the birds were instead using an ordinal strategy, i.e. a template for which brackets could occur in which positions, they would not respond correctly to a sequence which combined two bracket pairs that had occurred in the same position in the training stimuli. This strategy would allow for correct performance on swap trials, in which the innermost pair of brackets from one trained set occurred along with the outer pairs of a different set. However, in order to test whether the crows were using this strategy, the authors designed another type of trials, termed joint trials, on which this strategy would not produce center-embedding. Joint trials also combined bracket types used in different sequences, but contained sets of brackets that had occurred in the same position (e.g. outer, middle, inner) in each of the two trained sequences, rather than one set from each position as in swap trials. For example, a joint trial could contain the first and second pairs of brackets (purple curly and pink square) from List 1, and the second (green square) pair of brackets from List 2.

### C Response structure (examples with two transfer trial types)

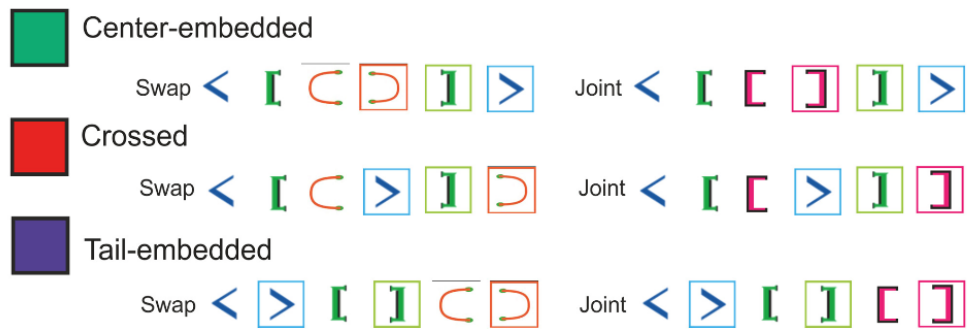


Figure 5.25: Brackets used in swap and joint trials, with examples of possible response structures, Liao et al. (2022).

The use of joint as well as swap trials made it possible to confirm that the crows were truly generalizing a center-embedded pattern. The crows performed above chance on both swap and joint trials; i.e. they generated center-embedded sequences at greater than chance frequency in both trial types. This suggests that they had generalized the abstract pattern of center-embedding instead of simply following a template (i.e. which types of brackets could occur at certain positions in a sequence).

Interestingly, the crows produced center-embedded patterns more consistently than the monkeys tested with a similar paradigm in Ferrigno et al. (2020). They also produced these patterns at a rate similar to that of human children in the same study. These findings suggest another remarkable convergence between humans and songbirds with regard to the processing of center-embedded patterns.

Like the animal sequence learning observed in earlier experiments such as Gentner (2006) and Abe & Watanabe (2011), these interesting results may still be amenable to an explanation not involving the animal subjects learning recursive rules. Rey and Fagot (2023) lay out such an explanation, involving a two-stage associative learning process. They note that, in learning to produce two-bracket sequences like { [ ] }, the birds would have been trained to peck the borderless open brackets first (the first stage of associative learning). After choosing

two open brackets, they would select the closed bracket matching the most recently opened bracket, a pattern learnable from the training sequences in which these two brackets were adjacent (the second stage). Finally, the only remaining selectable bracket would be the one corresponding to the first open bracket. This process could account for the results of Experiments 1 and 2.

In Experiment 3, the crows would have selected all the (borderless) open brackets first, and then the closed bracket matching the most recently selected open one, producing a partial sequence like < [ ( ) ]. The problem remains of how they would have chosen the final two brackets using associative learning, which Rey and Fagot do not explain. However, Rey and Fagot (2023) note, in support of their associative learning account, that the crows performed better (produced more embedded sequences) on swap than joint trials because in these trials, they would have seen the innermost pair of brackets in a training sequence. In these cases, however, the associative learning account does not seem to explain why the crows could produce center-embedded three-bracket sequences, at rates well above chance, in both swap and joint trial types. This suggested alternative explanation of associative learning also raises the question of parsimony: whether it is more reasonable to assume that an animal has learned a relatively simple recursive rule, or a more elaborate and possibly more memory-intensive set of rules that do not involve recursion but would produce the same results.

### **5.3.2.3. Summary: animal comprehension of center-embedding**

Summing up the animal research discussed in Section 3.2. above, there is both observational and experimental evidence that non-human primates and songbirds can learn center-embedded recursive patterns, and in addition there is some experimental evidence for basic dependency recognition by non-primate mammals, namely rodents.

First, as seen in Section 3.2.1, some avians and primates perform rituals of courtship or greeting with a simple A-B-A structure, wherein an important action is “bracketed” on both sides

by specific behavioral gestures. Another animal behavior of possible relevance to center-embedding is the construction of symmetrical display areas by bowerbirds, which display bilateral symmetry like the human art forms discussed in Section 3.1.5. Long-distance dependencies also occur in birdsong, including multiple dependencies in crossed (though not center-embedded) patterns. Examples of simple A-B-A type patterns have also been observed in the vocalizations of gibbons and New World monkeys, as well as in birds. Though the evidence is sparse, it is suggestive of the possibility that the basic cognitive functions behind linguistic center-embedding are language-independent and not unique to humans.

Clearer evidence for animals' ability to process center-embedding patterns comes from a variety of experiments with songbirds, rodents, and primates, which is covered in Section 3.2.2. Starlings, for example, can learn to recognize sequences of the form  $A_nB_n$ , which can be analyzed as featuring center-embedding, although they are also amenable to other analyses that do not require a recursive grammar. Experiments with simple A-B-A center-embedded sequences provide stronger evidence that some nonhuman species – songbirds, rodents, and primates – are capable of learning and generalizing these patterns. Finally, the strongest evidence for the ability to process center-embedded sequences comes from experimental paradigms involving longer palindromic or bracket sequences. These sequences have been used in auditory form with songbirds, and in visual form with primates and crows. At least some of the animal subjects were capable of learning to recognize complex embedded patterns, and importantly, to generalize them to new sequences – even though the learning process may take hundreds or thousands of trials. These findings imply that the cognitive faculties for center-embedding, or at least long-distance dependency processing, may be quite widely phylogenetically dispersed, at least among mammals and birds (especially passerines).

However, some issues remain difficult to resolve, such as whether the animals could be using other types of strategies to solve the task. Alternate explanations, such as count-and-match and substring recognition, cannot always be ruled out, and pattern recognition

may take hundreds or thousands of trials over weeks or months of training. Furthermore, humans seem to excel at these tasks with less training and effort than animals. Studies like Fitch et al. (2004), Jiang et al. (2018), and Ferrigno et al. (2020) show humans readily picking up patterns which nonhuman primates either never seem to master or take extensive training to acquire. However, Liao et al. (2022), present seemingly more robust evidence of birds learning these patterns within the same paradigm, but see also Rey & Fagot (2023) for a plausible rebuttal to the recursion claim.

### **5.3.3. General conclusion**

As discussed above in Section 1, center-embedded patterns appear in a wide variety of human nonlinguistic activities and artifacts, at greater breadth and depth than would be expected given the relatively limited and language-contingent manifestation of center-embedding in language. These domains include multi-person discourse, narratives, poetic rhyme and meter, rituals, music, visual art, and everyday actions. The appearance of center-embedding in these diverse areas, and the presence of greater embedding depth, suggests that center-embedding in language is an exaptation from more general ritual/task-planning abilities, and is limited in language by factors of real-time processing and semantics, as explored in Chapters 1 and 2.

As explored in Section 3.2, animals may also have the ability to recognize and generalize center-embedded patterns. Evidence for center-embedding in natural animal ritual (including vocalization) is limited, but plausible. Stronger evidence comes from a variety of experimental data, mostly involving primates and songbirds. However, animals may take substantial training to recognize a center-embedded pattern (of a sort that humans grasp easily), not all animal subjects show the same ability to learn these patterns, and it is not always possible to rule out alternative, simpler forms of pattern recognition.

In contrast to other species, humans show an aptitude for center-embedding across a strikingly wide-range of behavioral domains, including language. While center-embedding is limited in language due to working memory burdens, its significantly greater prevalence in SOV languages (see Chapter 2) implies that there is no hard grammatical constraint against center-embedding. Rather, the difficulties it presents come from the exaptation of a nonlinguistic cognitive feature involved in relatively long-term task planning onto the “bottleneck” of language. In summary, the parallels between linguistic syntax, the human activities discussed in the first section of this chapter, and some animal cognitive and behavior capabilities suggest a plausible origin for linguistic recursion as an exaptation of pre-existing cognitive abilities that are elaborated more in humans than in other species.

## **6. Learnability of simple dependency patterns by starlings**

### **6.1. Background: dependencies in language and nonlinguistic strings**

Long-distance dependencies between constituents – e.g. between a subject and its verb – are an essential aspect of human language. However, there is some evidence from animal studies that dependencies are prelinguistic: animals that do not have complex communication systems comparable to human language can learn to recognize and generate such patterns. In nonlinguistic sequences, a dependency may consist of two nonadjacent identical or perceptually similar elements (Gebhart et al. 2009), or a pair of elements that consistently co-occur (de Vries 2008). The present experiment looks at the ability of songbirds to learn to recognize simple dependencies (A-B-A) in auditory sequences.

#### **6.1.1. Prior experiments: dependency recognition by starlings and other songbirds**

There is already some evidence for long-distance dependency recognition in oscines (song birds), a clade which exhibits complex learned communication; results for starlings and finches are discussed in Section 2 of CAs demonstrated by Gentner et al. (2006), starlings can recognize patterns of the form  $A_n B_n$ , although whether these patterns exemplify or require center-embedding is not entirely clear (Corballis 2007, Rogers & Pullum 2011). These findings, along with evidence of long-distance dependencies in the songs of the birds themselves (Sainburg et al. 2019, Searcy et al. 2002), suggest that some form of auditory dependency recognition may be common across songbirds. Thus, there is evidence that the cognitive factors underlying linguistic dependencies, including center-embedding, can exist without language, and are thus shared with other (distantly related) species. However, it is often difficult to rule out the possibility that the birds are using a form of pattern recognition that does not rely on dependencies, such as counting or recognizing substrings.

The present experiment was an attempt to extend on the work of Gentner et al. (2006), to test whether European starlings could learn to distinguish simple dependency patterns of the



A-B-A form from patterns with the same elements in a different order, e.g. A-A-B. The paradigm of these stimuli is based on that of Murphy et al. (2007), who used visual stimuli with rats as subjects. These patterns unambiguously display center-embedding, i.e. a B element inserted between two matching A's, although they may also be amenable to other forms of pattern recognition, such as recognizing the presence or absence of two adjacent identical elements. Once a bird had consistently learned to classify multiple sequences following this pattern, I explored the possible alternative strategies by using test stimuli, as detailed below (Section 6.2.1.3.2.2).

## **6.2. Experiment**

### **6.2.1. Methods**

#### **6.2.1.1. Subjects**

Data was collected from 3 wild-caught adult European Starlings (*Sturnus vulgaris*).

#### **6.2.1.2. Stimuli**

All stimuli used in this task were artificially generated sequences of three or four starling song motifs. Each motif was 800-1000 ms in length, and they were separated by silences of 200 ms. Motifs are designated with capital letters in tables and graphs below.

In the first phase of the task, the bird was trained to distinguish two specific sequences of motifs: A-B-A and A-A-B, i.e. a sequence with a long (i.e. non-adjacent) dependency between the two identical elements versus one where those elements were adjacent. Subsequent phases added new training strings and tested the birds' ability to generalize this pattern; the types of stimuli used at each phase are detailed under Procedure below.

### 6.2.1.3. Procedure

#### 6. 2.1.3.1. Experimental setup and preliminaries

Each bird was housed individually in an operant conditioning chamber that was acoustically isolated, with a feeding apparatus that was activated by performing trials. Birds were given water and cuttlebone freely, and supplemental food as needed (e.g. if the apparatus was not functioning or they were not performing well enough to get sufficient food every day).

The experimental apparatus is depicted in Figure 6.1.

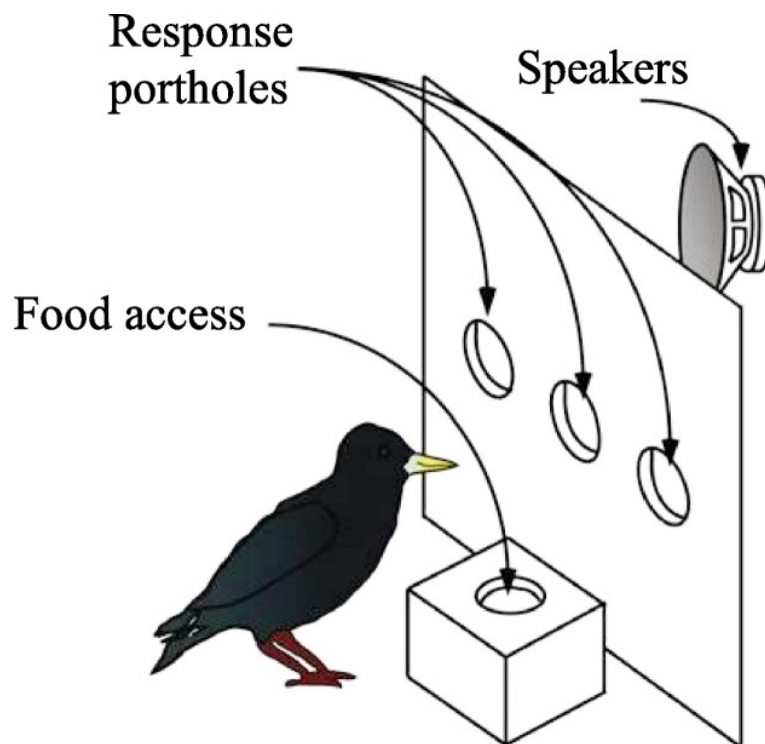


Figure 6.1: Illustration of an avian participant with the apparatus used in this study.

Initially, the birds went through a shaping procedure to learn to use the feeding apparatus. In the first stage, the center port would light up at random intervals (between 10 and 40 seconds) and then the food hopper would come up for five seconds, training the bird to associate the light with food. The second stage began when the bird pecked at the central port; during this stage of training the food hopper would come up for three seconds when the central port was pecked. After the bird had performed 100 trials in the second stage, the third shaping

stage began. At this stage, the central peck-port would flash, and once the bird pecked it, either the right or left port would light up, and then the bird would need to peck the lighted port to receive food. Again, the bird had to perform 100 trials at this stage before advancing to the fourth shaping stage. At this final stage, trials followed the same procedure as the previous stage, except that the central port did not flash but was constantly lit. Finally, after 100 trials at stage four, the experimental task proper began; this task is described by stages below.

### **6.2.1.3.2. Task structure**

#### **6.2.1.3.2.1. Individual trials**

The subsequent task employed the following trial structure. A bird was able to initiate trials at any time by inserting its beak into the central peck-port. After doing this, the bird heard a stimulus and then had to respond within a two-second window. These sequences were coded as either go-right or go-left. In this experiment, strings with a center-embedded (e.g. ABA) structure were go-left, while those that were differently structured (e.g. AAB) were go-right. Pecking the correct port for a given stimulus type resulted in a food reward. Pecking the wrong port resulted in the lights going out for 10 seconds, followed by a correction trial (described below) for the same stimulus. If the bird did not respond within the two-second window, the apparatus reset (with no feed or lights-out) and a new trial could be initiated; these trials were coded as “no response” and not included when calculating correctness rates.

When the bird pecked the incorrect port on a normal trial, it was given the same sequence again when it initiated a new trial (a *correction trial*). The bird did not receive a food reward on correct responses to correction trials as it did on normal trials. Correction trials would continue until the correct response was given, at which point normal trials resumed.

The test trials that were added in the testing phases (which are described in the subsequent subsection) were initiated the same way as normal trials, i.e. by the bird pecking the central button. These trials employed random reinforcement rather than rewards for a correct

response. That is, whether the bird's response was correct or incorrect, a reward would be given 50% of the time.

A *session* (used to measure the birds' performance over time) was defined as a block of 100 normal trials, plus whatever correction trials were needed, and test trials in generalization phases. Performance on a session was measured as percentage of correct responses on all normal trials, disregarding no-responses.

#### **6.2.1.3.2.2. Training and testing phases**

In the very first training phase (Training 1), the bird was trained to distinguish two strings using the trial structure detailed above: ABA (go left) and AAB (go right). Once the bird was performing stably above chance (10 consecutive sessions above 65%) on these two sequences ABA/AAB, the additional sequences BAB and BBA were introduced to the set of stimuli. These four strings constituted Training 2. Next, once performance was stable above chance (20 sessions above 65%) on all four strings, the first testing phase began. Table 6.1 lists the training and testing phases, and the strings introduced at each phase.

Testing phases employed test trials (as defined above) along with normal and correction trials. In Testing 1 and 2, the bird was exposed to strings following the previously learned patterns, but composed of new motifs. For example, once trained to criterion on the set of four strings in Training 2 {ABA, BAB, AAB, BBA}, the bird would receive {CDC, DCD, CCD, DDC} as test strings in the Testing 1 phase. These test strings were randomly reinforced (i.e. a 50/50 chance of feeding regardless of response) rather than reinforced on the correct answer, in order to evaluate whether the bird was generalizing the pattern it had learned to new strings. These test strings are marked in italics in Table 6.1. Performance above chance on each new set of test stimuli was taken to indicate successful generalization of the pattern, as opposed to simple memorization of the first few learned strings.

Table 6.1: Training and test stimuli for each phase of task

| Phase      | Strings                       | Left                                                               | Right                                            |
|------------|-------------------------------|--------------------------------------------------------------------|--------------------------------------------------|
| Training 1 | 2                             | ABA                                                                | AAB                                              |
| Training 2 | 4                             | ABA BAB                                                            | AAB BBA                                          |
| Testing 1  | 4 +<br><i>4 test strings</i>  | ABA BAB +<br><i>CDC DCD</i>                                        | AAB BBA +<br><i>CCD DDC</i>                      |
| Training 3 | 8                             | ABA BAB CDC DCD                                                    | AAB BBA CCD DDC                                  |
| Testing 2  | 8 +<br><i>4 test strings</i>  | ABA BAB CDC DCD +<br><i>EFE FEF</i>                                | AAB BBA CCD DDC +<br><i>EEF FFE</i>              |
| Training 4 | 12                            | ABA BAB CDC DCD<br>EFE FEF                                         | AAB BBA CCD DDC<br>EEF FFE                       |
| Testing 3  | 12 +<br><i>4 test strings</i> | ABA BAB CDC DCD<br>EFE FEF +<br><i>ABBA CBBC</i>                   | AAB BBA CCD DDC<br>EEF FFE +<br><i>ABBC CBBA</i> |
| Testing 4  | 12 +<br><i>6 test strings</i> | ABA BAB CDC DCD<br>EFE FEF +<br><i>AAA BBB CCC DDD<br/>EEE FFF</i> | AAB BBA CCD DDC<br>EEF FFE                       |
| Testing 5  | 12 +<br><i>2 test strings</i> | ABA BAB CDC DCD<br>EFE FEF                                         | AAB BBA CCD DDC<br>EEF FFE +<br><i>ABC DEF</i>   |

In training phases 3 and 4, the test strings for the prior test phase (1 and 2 respectively) were added to the training set, i.e. they were reinforced in the same way as described in Section 6.2.1.3.2.1. For example, in Training 3, the strings composed of motifs C and D were added as reinforced strings along with the already-learned strings composed of A and B motifs; Testing 2 likewise added test strings with motifs E and F, and these were then incorporated into Training 4, creating a full set of 6 go-left and 6 go-right strings. When performance on all training strings was stably above chance (at least 10 sessions above 65%) then the next testing phase commenced, and so on.

Once performance had become stable (as defined above) on all 12 of the ABA/AAB pattern strings in Training 4, all of which were being reinforced at this point, further non-reinforced test stimuli were introduced to determine which of several possible strategies the bird was using to solve the task. While persistent correct performance might be taken to indicate learning and generalization of a simple ABA embedded pattern, this is not the only way a bird could classify the strings. For example, correct performance on the 12 learned strings could be accounted for by an alternative rule: go right for any string containing an adjacent pair of identical motifs (e.g. BB). This would not constitute generalization of a center-embedded pattern, but a simpler form of pattern recognition. These test stimuli in test phases after Training 4 were introduced only as randomly reinforced test strings, and not incorporated into the training set.

The following sets of strings were used at subsequent testing stages. The coding of these strings as “go-left” or “go-right” refers to the way they would be classified if the bird was correctly generalizing the center-embedded rule; i.e. go left for strings in which the first and last motif are identical, go right otherwise.

#### **6.2.1.3.2.2.1. Testing 3: ABBA, CBBC (go-left); ABBC, CBBA (go-right)**

These strings were intended to clarify whether the birds were classifying strings based on match between first and last motif, or on the presence of two identical adjacent motifs. In the former case, if the bird is paying attention to the identity of the first and last segments, it would be expected to go left for strings like ABBA and right for those like ABBC (this is coded as “correct” classification). On the other hand, if the bird was using the criterion of two identical motifs to classify strings as “go-right,” it would go right on all of these strings.

#### **6.2.1.3.2.2. Testing 4: AAA, BBB, CCC, DDD, EEE, FFF (go-left)**

As with the length-4 strings in Testing 3, the intention with these stimuli was to determine whether the bird was classifying strings by one of two strategies: go left if the first and last segment match, or go right if two adjacent segments match. Under the former approach, all of the AAA-type strings would be classified as left; under the second, they would be classified as right. On these strings, “correctness” was coded as going left.

#### **6.2.1.3.2.3. Testing 5: ABC, DEF (go-right)**

These strings served to further clarify whether the bird was classifying strings based on the presence of two adjacent motifs (for which its response is go right) or a match between first and last motifs (which elicit a go-left response). Under the former approach, ABC-type strings would elicit a go-left response consistently; under the second, they would be classified as right. For these strings, correctness was coded as going right.

#### **6.2.1.4. Analysis**

Performance in testing phases was measured using a two-tailed t-test to compare performance on normal (reinforced) trials to test trials within the same sessions. If there was no significant difference between normal trials and test trials during these phases, this was taken to mean that the bird was generalizing the intended pattern to the new test stimuli.

### **6.2.2. Results**

Two of the three subjects, Bird 1 and Bird 3, were not successful on the basic task; i.e. performance on the first four trained strings was not significantly over chance after ~300 sessions. However, Bird 2 displayed above-chance performance at around 200 sessions and was therefore advanced to the testing phases. In this section, I will track the performance of Bird 2.

### 6.2.2.1 Testing 1-2 and Training 3-4

In these phases, once the bird had been successfully trained on the four strings of Training 2, it was given two successive sets of test strings following the same ABA/AAB paradigm with new motifs. After each testing phase, these strings were incorporated into the training set, i.e. performance on them was reinforced. Figure 6.2 shows the successful bird's performance on stages from Training 2 (four strings) through Training 4 (twelve strings), demonstrating its generalization of strings within the ABA/AAB paradigm.



Figure 6.2: Successful performance of one bird on generalizing to newly introduced test strings (blue dotted line = CD and purple dotted line = EF), which after the testing phase were integrated into the trained strings (yellow solid line = AB/CD and green solid line = AB/CD/EF). Horizontal lines represent 50% and 65% correct performance.

At each of the first testing stages, 1 and 2, the bird's performance on the introduced test strings was the same as on previously learned strings (Testing 1:  $t(52) = 1.36$ ,  $p = .178$ ; Testing



2:  $t(9) = .861$ ,  $p = .41$ ). These test phases are illustrated by the blue and purple dotted lines in Figure 6.2.

#### 6.2.2.2. Testing 3-5

Figure 6.3 shows the bird's performance on the twelve learned strings together with its performance on new sets of test strings, each of which is discussed in more detail below.



Figure 6.3: Bird performance on continued training trials with 12 reinforced strings (green solid line) and additional testing string sets (dotted lines). For test strings, “correctness” is coded as conformity with a hypothesized response pattern to a generalization of the “go left on ABA pattern” rule. Horizontal lines represent 50% and 65% correct performance.

#### **6.2.2.2.1. Testing 3: ABBA, CBBC (go-left); ABBC, CBBA (go-right)**

These were the first set of test strings added after the bird had learned the twelve strings (gold dotted line in Figure 6.3). As described under Methodology, the Testing 3 strings were intended to disambiguate two hypotheses concerning the bird's strategy for classifying the ABA/AAB strings. Above-chance performance on all these strings – i.e. consistently classifying ABBA and CBBC as go-left, and the others as right – would mean that the bird was generalizing the first/last match rule.

A plausible alternative strategy would be going right on all strings containing a doubled segment, such as BB. This strategy would produce a pattern where “correct” performance is very high on non-match strings and very low on the others. Performance on these stimuli, however, was around chance and did not consistently show either pattern. The bird's performance on these four strings was significantly lower than performance on the twelve learned strings at the time ( $t(49) = 2.37$ ,  $p = .02$ ). Neither of the hypothesized patterns clearly emerges for individual strings (see Figure 6.4.)

Performance on the go-left strings ABBA/CBBC was also significantly lower than for go-right strings ABBC/CBBA ( $t(104) = -3.1$ ,  $p < .005$ ). This showed that the bird had a rightward bias, perhaps demonstrating a tendency (though not consistent) toward classifying strings based on the presence of two adjacent elements. In summary, the bird's responses to this testing stage suggested that it may have been classifying strings based on the presence of two adjacent elements, but the results were not entirely clear. The subsequent sets of test strings all exemplified one pattern that the bird would classify consistently if it was using a particular pattern match strategy.



Figure 6.4: Performance on individual strings in Testing 3 (dotted red line on Figure 6.3) The red and purple strings ABBA, CBBC are coded as go-left strings; the other two as go-right strings. Horizontal lines represent 50% and 65% correct performance.

#### 6.2.2.2.2. Testing 4: AAA, BBB, CCC, DDD, EEE, FFF (left)

The intention of Testing 4 was to further clarify whether the bird was classifying strings by one of two simple strategies: go left if the first and last segment match, or go right if two adjacent segments match. Strings consisting of three adjacent motifs fit both criteria. Under the former approach, AAA-type strings would be classified as left; under the later, they would be classified as right. Here, “correctness” was coded as go-left. No significant difference was observed between performance on AAA-type strings and the learned ABA/AAB stimuli ( $t(18) = .17, p = .86$ ), suggesting that the bird was in fact generalizing the pattern. Over 10 sessions with these test strings, the bird tended toward going left at above chance rates, suggesting it was generalizing the intended pattern, although performance fluctuated noticeably, as can be seen in Figure 6.5.



Figure 6.5: Performance on individual strings in Testing 4 (dotted green line on Figure 6.3). Horizontal lines represent 50% and 65% correct performance.

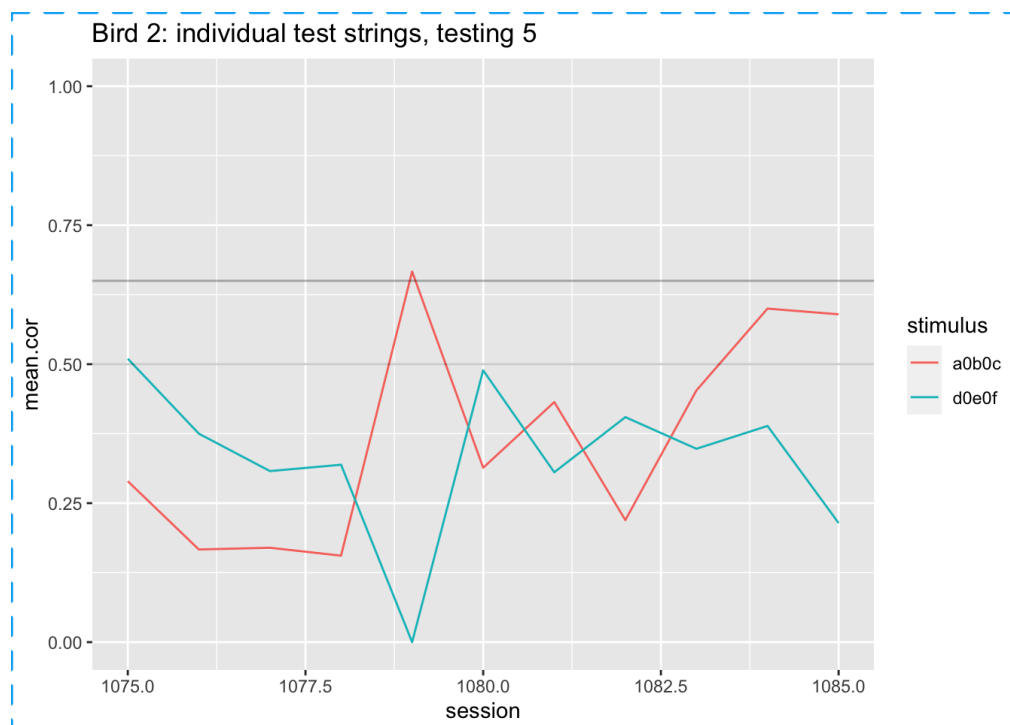


Figure 6.6: Performance on individual strings in Test 5 (dotted blue line on Figure 6.3)

#### **6.2.2.2.3. Testing 5: ABC, DEF (go-right)**

On the other hand, in Testing 5, the bird went right at below chance – i.e. it preferred to go left on these strings ( $t(19) = 6.7, p < .001$ ). This suggests that the bird was classifying these strings based on the absence of two adjacent identical elements, a feature for which it had been previously trained to go right. The “correct” response for the two strings ABC and DEF would have been to go right, because they do not represent the center-embedded ABA pattern.

#### **6.2.3. Discussion**

My results with the one successful bird contribute to the evidence that avians can learn to recognize dependency patterns in auditory sequences (see also Abe & Watanabe 2011, Gentner et al. 2006). Once the successful bird learned the pattern exemplified by the initial four sequences (ABA / BAB vs. AAB / BBA) it generalized quickly and with the same rate of accuracy to newly added sequences exemplifying the same patterns with different elements, demonstrating that it had not only memorized the specific sequences but learned the pattern which they exemplified.

However, the results of the later test phases are not entirely clear as to whether the successful bird was relying on a strategy involving a simple dependency (the first and last element of the string are identical) rather than a more “local” strategy, i.e. listening for adjacent identical motifs. In the case of the strings ABBA and CBBC, and their non-match counterparts, the bird’s performance did not show a very clear tendency toward classifying strings based either on two adjacent identical motifs, or on a match between first and last motif. The results from AAA-type strings were clearer: the bird classified these as go-left, although they could also have been classified as go-right based on the presence of two adjacent identical motifs. Strings with three different motifs, e.g. ABC, were predominantly classified as go-left, suggesting a generalization of a tendency to go right on strings with two adjacent identical motifs, and left otherwise. In general, the bird may have been attentive to both patterns as criteria for classifying

strings because it had been very extensively trained to distinguish ABA and AAB patterns, and when confronted with strings that exemplified both or neither of these patterns, its classifications were not always consistent.

As in previous animal studies involving recursive sequence learning (e.g. Gentner et al. 2006, Jiang et al. 2018), not all of the animal participants were successful at the basic task. Two birds out of the three initially tested did not achieve consistently higher than chance performance on the first four strings (ABA/BAB and AAB/BBA) after around 300 sessions. The bird that did succeed, Bird 2, did manage to generalize this pattern after extensive training, and had some success with additional training and testing. These results suggest that among starlings, as among other nonhuman species, ability on center-embedding pattern recognition tasks can vary greatly across individuals. This may reflect different aptitudes for center-embedding in particular, or other cognitive factors.

## **Chapter 7. Conclusion**

In the preceding chapters I have presented a wide-ranging overview of the syntactic phenomenon of center-embedding, across different languages and beyond language, combining evidence and methodology from multiple disciplines. To conclude, I will recapitulate the important findings, and highlight some greater issues and directions for further research.

### **7.1. Recap of the previous chapters**

Chapters 1 and 2 looked at center-embedding across natural languages. The general picture that emerges is that center-embedding is rare and difficult across languages – but perhaps not so much as previously assumed. First, the prevalence of center-embedding varies between languages with word order and possibly with morphological factors, as shown in Chapter 2. Second, the same facilitating syntactic and semantic factors appear across different languages. These observations suggest that the difficulty of center-embedding is an issue of processing and memory, not inherent syntactic constraints, and its acceptability is contingent on both universal and language-specific factors.

Taken together, the typological and experimental evidence surveyed in Chapter 1 reveals that while center-embedding generally presents processing difficulties, its acceptability and processability vary across languages. Both language-specific and universal cognitive factors are involved. For example, in Japanese and Korean, variation in case marking may facilitate the acceptance of multiple center-embedded complement clauses, which are effectively forced by the default SOV order. In addition to these language-particular factors, a variety of common factors have been observed to make center-embedding more acceptable across typologically different languages. These include combinations of clause types that lessen dependency length or avoid creating multiple long dependencies (e.g. complement clauses in C1 with relative clauses in C2, rather than vice-versa), avoidance of new referents (especially new subjects, but possibly also verb tense) in embedded clauses, and avoidance of

similarity-based interference. In general, syntactic center-embedding is constrained by the exigencies of real-time sentence processing and working memory, especially in spontaneous language.

Chapter 2 further explores and confirms the reality of these facilitating factors, along with the role of typology in the prevalence of center-embedding, with a new corpus study. The hypothesis that languages with SOV order should permit more center-embedding than those with SVO or mixed head order was confirmed. In addition, examination of corpus search results along with some observed examples confirmed that some of the important factors shown to facilitate processing of multiple center-embedding in an experimental setting (e.g. pronoun or quantifier subjects rather than descriptive subjects in embedded clauses) are also prevalent in naturalistic data. This observed cross-linguistic variation confirms that center-embedding is not absolutely disfavored, but that language-specific factors along with universal cognitive factors, such as working memory, play a role in the processing of center-embedding.

Chapters 3 and 4 present the results of several sequence-learning and artificial language experiments designed to test the learnability of center-embedding, or elicit the emergence of new center-embedded patterns. In the iterated sequence learning experiments detailed in Chapter 3, center-embedded patterns generally did not appear from initially unstructured input at levels above chance, and such patterns did not persist when initially introduced. However, it was also found that the presence of a repeated character in the strings seen by the first participant, creating a simple dependency, may “seed” center-embedding in subsequent generations – which possibly represents a transition from a finite-state to a context-free grammar. All of these results are consistent with the general disfavoring of center-embedding in language, and the role of working memory constraints therein.

Chapter 4 presents another two experiments involving a meaningful artificial language. The first experiment compared the learnability of three dependency types (center-embedding, crossed, and branching), and the second employed iterated learning to observe the emergence



of dependency types with initially unstructured input. In both cases, the results showed that branching dependencies were the most learnable of the three types, and center-embedding the hardest. Center-embedded dependency structures are difficult to learn in artificial languages, and do not readily arise through iterated learning (at least with English-speaking participants). On the other hand, crossed-dependency grammar was no harder to learn than center-embedding, and there were suggestions in our data that crossed grammars were more likely to be faithfully reproduced, and to emerge as a modification of either center-embedding or initially unstructured input. This is surprising, given evidence in other artificial language learning tasks that learnability and typological frequency are often aligned, and considering that crossed dependencies are almost nonexistent in natural languages, whereas center-embedded dependencies do appear widely despite the processing difficulties they may present.

Chapter 5 looked beyond language, and beyond humans, to explore evidence for the general hypothesis that linguistic recursion, and specifically center-embedding, is an exaptation from non-linguistic cognition. Here, I have explored the provocative question raised by Hauser, Chomsky and Fitch (2002): where did recursion come from? A potential answer to this question has been suggested several times in different academic disciplines, and I have attempted to bring together these diverse currents of research in this dissertation in support of the possibility that linguistic recursion was exapted from a more general ability to plan complex sequences of actions. Frits Staal's relatively obscure anthropological work on Vedic ritual, in which he proposed ritual behaviors as the origin of recursive syntax, is of particular interest. The prevalence of center-embedded structure in various areas of human activity that are linked to ritual (music, narratives, art), and its possible appearance in some animal activities (e.g. courtship and greeting rituals, as well as trained behaviors in experimental settings), lend support to this evolutionary story.

Chapter 6 offers additional experimental evidence that the ability to process center-embedding is not limited to humans. Three starlings were trained to distinguish center-embedded patterns of the simple A-B-A form from other patterns, although only one was fully successful. As with previous experiments involving animals' ability to learn center-embedded patterns, it is not entirely clear whether the bird was recognizing the center-embedding as such, or using other strategies (i.e. the presence and absence of adjacent identical motifs) to distinguish different types of strings. Nonetheless, these results contribute to the evidence that nonhuman species have some capacity to learn center-embedded patterns.

## **7.2. Greater implications: center-embedding as an evolutionary vestige**

The ubiquity of center-embedding in human nonlinguistic (and to some degree non-human) activity and cognition presents an anomaly when contrasted with the relative sparsity and difficulty of center-embedding in language. While action sequences seem to be effectively unbounded in center-embedding depth (Pulvermüller 2014), clausal center-embedding tops out at three levels, even with such facilitating devices as pronoun subjects and easily processable clause types (e.g. subject relatives and nonfinite constructions) to decrease processing load. This depth limit appears to hold even in SOV languages, which (as revealed in the corpus data analyzed in Chapter 2) allow center-embedding to occur more pervasively, and also facilitate center-embedding with devices such as varying case marking. As shown in Chapter 4, there is also experimental evidence that center-embedding may be more difficult to learn and process than crossed dependencies, a structure very rare in natural languages.

This discrepancy between the linguistic and nonlinguistic domains raises several theoretical questions concerning the role of recursion and center-embedding in language evolution, a much-debated issue. Hauser et al. (2002), for instance, propose recursion as the *sine qua non* of human language, and suggest (but do not explore in detail) the possibility of a

non-linguistic origin, citing cognitive faculties such as navigation, social behavior, and numerical reasoning. Evidence from a range of human and animal behaviors, along with some experimental results, lends plausibility to this proposal.

As previously discussed in Chapter 1, center-embedding is limited in language by processing issues which manifest more generally in structures such as relative clauses, e.g. the greater dependency length of object relative clauses and the complexity added by descriptive noun/determiner phrases and tensed verbs. Center-embedding also creates particular challenges for working memory which make it less tractable in spontaneous speech; as determined by Karlsson (2007, 2020), center-embedding is tolerated in writing, though still limited, but very rare in unplanned informal speech. These factors that make center-embedding difficult in spontaneous language – semantic information combined with the exigencies of real-time working memory – are lessened or entirely absent in the nonlinguistic domains discussed in the first half of Chapter 5. As Staal (1979: 19) argued with regard to ritual, the greater embedding depth permitted in nonlinguistic action sequences than in language suggests that linguistic embedding is an exaptation of action planning, and Pulvermüller (2014) makes a similar argument with regard to everyday activities.

Further observational and experimental evidence suggests that animals are capable of learning and enacting center-embedded patterns (as discussed in Section 2 of Chapter 5), even though this may take extensive training, and not all individuals learn successfully. In addition, humans tested with comparable tasks often perform far better than animals at learning and generalizing the relevant patterns (e.g. Ferrigno et al. 2020). Therefore it is evident that the basics of center-embedded cognition are present in nonhuman species, but not as well-developed as in humans.

These observations of center-embedding in a variety of nonlinguistic human behaviors and art forms, along with the abilities of animals to learn similar patterns to a more limited extent, suggest that the basic capacity for recursive cognition predates language and does not

require language. This rudimentary ability, possibly developed for rituals and complex task planning, would have been elaborated in humans, and then exapted into language.

Putting the above observations together, we have a plausible evolutionary story: linguistic center-embedding is an exaptation from the cognitive processes involved in planning and carrying out complex actions (ritualistic and utilitarian) to language, and is necessarily reduced in language by the previously discussed constraints imposed by semantics and working memory.

### **7.3. Some issues for further research: diachronic change and modality**

The evolutionary hypothesis summarized above also presents some open questions for further research, particularly concerning the transformation or attrition of center-embedding in diachronic language change, the possible impact of writing on the proliferation of center-embedding, and the appearance of center-embedding in signed languages.

#### **7.3.1. Diachronic change**

If it is assumed that center-embedding is disfavored in languages for the most part, we might expect to see this reflected in diachronic changes; i.e. languages would tend to shift toward syntactic patterns that do not produce center-embedding. Though data is sparse, there is some support for this contention. On the other hand, it is possible that writing and literacy may favor the proliferation of center-embedding, by reducing the burden it places on working memory. I will discuss each of these issues in turn.

##### **7.3.1.1. Center-embedding and word-order changes**

While SOV is the most common word order cross-linguistically, appearing as the default order in around 40% of languages (Dryer 2013b), it is also particularly conducive to clausal center-embedding, as explored in Chapters 1 and 2. This raises questions about the processing

difficulties presented by this word order, and whether the difficulty of center-embedding, in particular, might affect diachronic word order changes.

There is some evidence from historical linguistics that word order changes from SOV to SVO clausal order are more common than the reverse pattern (Givon 1979, Gell-Mann & Ruhlen 2011). Gell-Mann & Ruhlen (2011) also argue, on the basis of these known diachronic changes along with other phylogenetic evidence, that the earliest protolanguages were SOV, with SVO order emerging later in various language families. This change would result in center-embedding becoming less prevalent for the reasons detailed in Section 1.1 and Chapter 2 – i.e. SVO order does not force center-embedding of verbal complement clauses.

Some specific examples of SOV → SVO word order changes are well-known. For example, in late Latin, SOV order generally decreased and SVO increased over time, eventually leading to the predominant SVO order of the Romance languages (Ledgeway 2012: 222). This difference between Latin and its descendants is reflected in the corpus results discussed in Section 2.2: while the modern Romance languages have very low frequencies of center-embedding (some of the lowest in the corpus results), Latin has one of the highest rates. However, this result may partially reflect sampling biases in the corpora toward more formal literary material in Latin, and more modern, colloquial genres (such as internet conversation) in the modern languages.

A similar change from SOV to SVO order has occurred in the history of English (Lorido 2022). Old English had SOV order with post-nominal relative clauses, a combination that results in center-embedding of all relative clauses, but the frequency of SOV order decreased over time, giving way to SVO order as seen in later forms of English (Lorido 2022: 149). This transformation of word order may have been driven in part by avoidance of the difficult center-embedding construction (Ogura 2001, 2004; Lorido 2022: 158).

However, as usual in considerations of linguistic typology, processability is a relevant factor but cannot be the only factor (see also Chapter 4). As Ueno & Polinsky (2009: 704,

footnote) point out, while SOV order seems to present processing difficulties (including but not limited to center-embedding), it is nonetheless the most frequent basic word order in the world's languages (Dryer 2008). Whatever processing challenges are presented by center-embedding are, therefore, evidently not so insurmountable as to force languages to move away from SOV order entirely; as we have seen in Chapters 1 and 2, SOV languages can mitigate the difficulty of center-embedding with factors such as case marking and null subjects. The exact nature of the factors that shape these observed word order changes, and the possible role of center-embedding specifically, remains to be elucidated.

### **7.3.1.2. The possible role of writing**

Comparisons between spontaneous speech and written language with regard to center-embedding, and the possible impact of writing on the prevalence of center-embedding, also merit further attention, with regard to both the synchronic prevalence of center-embedding and possible factors in diachronic change. Writing allows for more pervasive and deeper center-embedding, by reducing the burden of on-line processing, as it generally allows greater syntactic complexity. Overall, clausal embedding is rarer and shallower in spoken language than written language (Sakel & Stapert 2010:11-12; Miller & Weinart 1998, Miller 2006ab, Auer 2009). In addition, evidence from studies of elderly persons' and aphasia patients' speech and writing shows that, as working memory capacity decreases, the ability to produce and comprehend syntactic embedding decreases. However, adults' use of complex subjects containing embedded clauses does not decline with age in writing as sharply as in speech (Kemper 1986, 1987; Kynette & Kemper 1987), providing further evidence that writing facilitates syntactic complexity and reduces memory load.

These observations about the contrast between speech and writing are generally upheld by corpus findings with regard to center-embedding in particular, as discussed in Chapter 2. In European languages, as observed by Karlsson (2007, 2020) center-embedding of clauses tops

out at three levels in written language, and two in spoken language; in both cases the maximum is very rarely seen in natural discourse. My own results, on a wider sample of languages, are consistent with what Karlsson reports.

Another factor of interest that merits more exploration is the impact of different written media and genres on the prevalence of center-embedding. The space constraints of social media, e.g. in journalism or on platforms such as Twitter, could plausibly force center-embedding in cases where there is not sufficient room for a more paratactic, multi-sentence expression of the same idea. Genre and style are also relevant; as observed by Martinez et al. (2022), for example, legal contracts have significantly more center-embedding than typical prose.

The relationship between center-embedding and writing also has interesting implications for diachronic language change. Karlsson (2007) takes the observed speech-writing discrepancy to suggest that the development of center-embedded clauses in European languages may have been influenced by writing, especially the Latin rhetorical style popularized by classical writers like Cicero. This style is based on so-called “periodic sentences,” which include multiple subordinate clauses and typically feature at least one center-embedding (Blatt 1957, Karlsson 2007). Blatt (1957) goes so far as to claim that complex subordinate clauses were rare in the Romance languages before around 1300, when syntax was influenced by scholarly Latin. The assumption that center-embedding *requires* writing to develop, however, obviously cannot apply to non-European languages without a tradition of writing. As discussed in Chapters 1 and 4, there are languages that were never written but do have pervasive and even obligatory center-embedding, such as Coahuilteco and Moru. The influence of Latin prose style probably cannot be discounted in the development of European languages, but neither can it be taken as a point of origin for center-embedding in these languages. However, it does raise the interesting possibility that the proliferation of literacy and writing could increase the

prevalence of center-embedding in languages; as observed by Kalmar (1985), this may be the case with clausal subordination more generally.

### **7.3.2. Center-embedding in signed languages**

Another open area of inquiry is the relationship between center-embedding and language modality. It is well-known that center-embedding is more prevalent in writing than in spontaneous speech, but a related question that is not well explored concerns the prevalence and nature of center-embedding in signed languages.

Since signed language is subject to the same general time pressures and semantic constraints as spoken language, the facilitating factors involved would be expected to be similar – including correlations between center-embedding and word order of the sort observed in Chapter 2. This notion is confirmed by Geraci et al. (2016)'s observations of Italian Sign Language. This sign language has head-final order and permits center-embedding of infinitival clauses. Finite clauses are only allowed to occur in center-embedded position if they have null pronoun subjects (Geraci et al. 2016: 108). As explored in Chapter 1 with regard to English, both infinitive clauses and clauses with null subjects are easier to process in center-embedded position because they lack overt subjects.

Interestingly, SOV default order is documented in several emergent sign languages, including Al-Sayyid Bedouin Sign (Sandler et al. 2005), and the earliest generation of Nicaraguan Sign (Senghas et al. 1997), although how this may impact the presence of syntactic center-embedding is not known. SOV order also tends to emerge in ad-hoc gestural descriptions of transitive actions regardless of the word order of the speakers' language (Goldin-Meadow et al. 2008, Schoustra et al. 2012, Meir et al. 2017); however, in some cases SVO order appears predominantly, especially when reversible events involving two animate subjects are communicated (Hall et al. 2014). In addition, SOV order has been observed in homesign systems developed by deaf children of non-signing parents (Goldin-Meadow &



Mylander 1998). Emergent sign languages that start out with SOV order would provide a potential real-time case study for the evolution of word order, and particularly center-embedding.

#### **7.4. Final thoughts and prospects**

Center-embedding is a syntactic phenomenon that has long raised important questions about human language with regard to issues including processing, recursion, and the evolution and cognitive basis of language. Many more important issues, particularly its possible role in diachronic word order change, its relationship to writing and genre, and its emergence and prevalence in signed languages. I leave these brackets open for further research.

## Appendix A. Analyzed Universal Dependencies Corpus Search Results

### SVO Languages

#### English

English EWT:

1. [C1 The fact that  
the US government and media are having a hissy fit over  
Venezuela wanting to buy guns,  
[C2 and then 200,000 of the guns  
[C3 Chavez wants  
to buy ]  
go missing on their way to Iraq ]  
is definitely sus.]

#### Finnish

Finnish FTB

2. [C1 Se ankara ja pyyteetön työ  
[C1 def hard.NOM and altruistic.NOM work.NOM  
[C2 jota yhtymä-mme vienti-osasto -  
[C2 which.SG.PART group-1PL.POSS export-department.NOM  
[C3 joka muuten raportoi suora-an min-ulle - ]  
[C3 which.SG.NOM by.the.way report.3sg.PRES direct-SG.ILL 1sg-ALL ]  
on kaikki nämä vuo-det harjoitta-nut lähinnä Ruotsi-ssa , Hollann-issa ja  
Ranska-ssa , ]  
have.3SG.PRES every these year-PL.NOM perform-PST.PRF mostly Swe-INESS Holl-INESS  
and Fr.-INESS ]  
on nyt vihdoinkin kantama-ssa hedelmä-ä laajemmalti-kin .]  
have.3SG.PRES now finally carry-INESS fruit-PART further ]

“The hard and selfless work that our group's export department - which, incidentally, reports directly to me - has done all these years, mainly in Sweden, the Netherlands and France, is now finally bearing fruit more widely.”

#### Italian

PUD

3. [C1 il perché  
[C1 the reason.why  
[C2 la linea ferroviaria  
[C2 the line railway  
[C3 che port-ava a Flensburg ]  
[C3 that go-3sg.IMPV to F. ]  
non fu mai utilizz-ata correttamente per l'evacuazione ]  
NEG was ever use-PTCP correctly for the.evacuation ]  
riman-e tuttora motivo di dibattito tra gli storici. ]  
remain-3sg.PRES still matter of debate among historians ]

“ The reason the railway line that goes to Flensburg was never properly used for evacuation remains a matter of debate among historians to this day.”

## PosTwita

4. [C1 il fatto  
[C1 the fact  
[C2 che una persona  
[C2 that a person  
[C3 che vada in discoteca ]  
[C3 who go-PRES in disco ]  
\_\_\_\_ ]  
imply-PRES that this REFL drug-PRES be-PRES a nonsense ]  
"The fact that a person who goes to the disco [V2] implies that they do drugs is nonsense."

## Spanish

Spanish AnCora:

5. [C1 La circumstancia  
[C1 DEF.F.SG fact  
[C2 de que el 80% de los turista-s  
[C2 of that DEF.M.SG 80% of DEF.M.PL tourist-PL  
[C3 que lleg-uen a Catalunya  
[C3 who arrive-3PL.PRES to catalonia  
lo hag-an por carretera ]  
INDEF.SG do-3PL.PRES by roadway ]  
restar-á trascendencia a los problem-as aeroportuario-s,  
reduce-3SG.FUT importance to DEF.M.PL problem-PL airport-ADJ-PL  
según el conseller de Indústria, Antoni Subirà. ]  
according.to DEF.M.SG minister of industry, A. S. ]

The fact that 80% of tourists who arrive in Catalonia do so by road will reduce the importance of airport problems, according to the Minister of Industry, Antoni Subirà.

## Swedish

Talbanken

6. [C1 Vad  
[C1 what  
[C1 de  
[C1 3PL  
[C2 som resonera-r så  
[C2 as reason-PRES so  
glömm-e-r  
forget-PRES ]  
  
är ]  
be.PRES]  
dels att kärlek-en inte alltid är beständig  
both.and that love-DEF.SG not always be.PRES constant  
och att den i all-a händelse-r inte är evig.  
and that 3SG in all-PL event-PL.INDEF not BE.PRES eternal

"What those who reason in this way forget is that love is not always lasting and, in any case, it is not eternal."

## Mixed headedness

### Dutch

#### Alpino

7. [C1 De driftig-e Amsterdammer-s,  
[C1 DEF hasty-PL Amsterdammer-PL  
[C2 die  
[C2 who  
[C3 hoe meer de tijd verstreek,  
[C3 how more DEF time run.out.PAST  
minder in eigen kunnen gingen geloven, ]  
less in own ability start.PAST believe.INF]  
zagen zich bedwongen en ten slotte verslagen door een Excelsior, ]  
see.PAST.PL self control.PAST and at last defeat.PAST by INDEF Excelsior]  
dat bekwaam bleek in vertrag-en en plotseling versnell-en.  
which capable prove.PAST in slow-INF and sudden accelerate-INF

“The hasty players from Amsterdam, who, as time passed, started to believe less in their own abilities, found themselves controlled and ultimately beaten by Excelsior, which showed itself capable of controlling the tempo of the game.” (E. Van Everbroeck)

8. [C1 De manier,  
[C1 DEF way  
[C2 waarop Ischa Meyer, de gevreesde toneel-recensent van HP Magazine,  
[C2 after.which I M DEF feared theater-critic of HP Magazine  
[C3 die vond  
[C3 who find.PAST  
dat Nederland geen goed-e acteur-s en actrice-s bezat ]  
that Netherlands NEG good-PL actor-PL and actress-PL have.PAST ]  
het moeras werd in-gedreven ]  
DEF.NEUT swamp IMPERF.PAST into-push.PTCP ]  
was "beschaafd kostelijk". ]  
be.PAST civilized entertaining ]

“The manner in which Ischa Meyer, the feared theater critic from HP Magazine, who had stated that the Netherlands didn't have any good actors or actresses, was taken to task [lit. driven into the swamp] was quite entertaining.” (E. Van Everbroeck)

9.  
[C1 Mensen als ik,  
[C1 people like 1sg  
[C2 voor wie het uiterste van wat  
[C2 for who the greatest of what  
[C3 mensen aan elkaar kunnen meedelen \_ ]  
[C3 people to each.other can communicate.INF ]  
op muziekpapier geschreven is, ]  
on music-paper written be ]  
halen meer uit de radio dan ze er als luister-geld instoppen. ]  
Get more from the radio than they listen-money put in ]

“People like me, who feel that the greatest communication happens through music, get more out of their radio license fees than they pay.” (E. Van Everbroeck)

## German

### GSD

10. [C1 ... die Franzos-en,  
[C1 DEF.PL French-PL  
[C2 von denen wir  
[C2 of DEF.PL.DAT 3PL  
[C3 was die Mode-n betrifft, ]  
[C3 DEF.PL fashion-PL concern.PRES]  
getreu-e Nachahm-er sind, ]  
faithful-PL imitate-AGENT.PL be.PL]  
die Nelke-n mit den rund-en Blätt-ern sehr lieb-en."]  
DEF.PL carnation-PL with DEF.PL.DAT round-PL leaf-DAT.PL very love-PRES.3PL]

..the French, of whom, as far as fashion goes, we are loyal imitators, love carnations with round leaves.  
(R Kluender)

### HDT

11.  
[C1 Intel-s Argument ,  
[C1 Intel-GEN claim  
[C2 der 2 Kilobyte große Daten-block ,  
[C2 that 2kp big data-block  
[C2 der aus dem BIOS in den Chip transferier-t wird ,  
[C2 that from DEF.DAT BIOS to DEF.ACC chip transfer-PRES be.PRES  
sei doch verschlüsselt und nirgends dokumentiert , ]  
be.SBJV really encrypted and nowhere documented ]  
nutz-t da wenig .]  
use-PRES so little ]

"The claim of Intel that the 2-kilobyte data block, that is transferred from BIOS to the chip, is alleged to be encrypted and nowhere documented, doesn't help much." (R Kluender)

12. [C1 Die zwei Gericht-s-verfahr-en gegen die Betreiber von Website-s ,  
[C1 DEF.PL two court-LINKER-case-PL against DEF.PL operators.PL of website-PL  
[C2 die das Programm DeCSS ,  
[C2 who DEF program DeCSS  
[C3 mit dem sich die Verschlüsselung ( CSS ) von DVD-s um-gehen lässt ,  
[C3 with DEF.ACC self DEF.PL encryption CSS of DVD-PL around-go  
allow-PRES  
zum Herunterladen bereit-stellen , ]  
for downloading ready-provide]  
sind zentrale Rechts-konflikte]  
be.PL central rights-conflict ]

"The two court cases against operators of websites, [who make the DeCSS program, [which can be used to get around CSS encryption] available for downloading,] are (represent) central conflicts of rights." (R Kluender)

13. [C1 Die Konferenz ,  
 [C1 DEF conference  
     [C2 die von manch-en Entwickler-n ,  
     [C2 which by many-PL.DAT developer-PL.DAT  
         [C3 die mit der freien Skript-sprache PHP arbeit-en ,  
         [C3 who with DEF free script-language PHP work-PL  
         fast schon als Pflichttermin angesehen wird , ]  
         almost already as obligation consider.PTCP be.PRES ]  
 hat sich im Vergleich zu ihrem Vorgänger deutlich ge-mauser-t ]  
 have.PRES self in comparison to 3SG.GEN forerunner clearly PERF-molt-3SG ]

"The conference, which is seen as almost obligatory by many developers, who work with the free script language PHP, has changed drastically [lit. molted its feathers] in comparison to its predecessor" (R Kluender)

14. [C1 Corel-s Paket ,  
 [C1 Corel-GEN package  
     [C1 das neben der       Spracher-kennung und einem Recovery Manager  
     [C1 which besides 3SG.GEN speech-recognition and INDEF R. M.  
     erstmal mit dem       Oxford Concise Dictionary  
     first.time with DEF.ACC O C D  
         [C2 ( das man in Deutschland allerdings nicht bekomm-t )  
         [C2 which one in Germany however NEG get-PRES  
         und Microsofts VBA aus-ge-liefer-t wird , ]  
         and MS VB out-PERF-roll-PRES be.PRES ]  
 glänzt bei der Text-verarbeitung und der Tabellierung mit neuen Funktionen .]  
 excels by 3SG.GEN text-processing and 3SG.GEN table with new functions ]

Corel's package, which in addition to its speech recognition and recovery manager is being released for the first time with the Oxford Concise Dictionary, which one however cannot get in Germany and Microsoft's VBS, excels in its text processing and tabulation functions. (R Kluender)

15. [C1 Die fein-e Ironie ,  
 [C1 DEF fine-F irony  
     [C2 mit der ein-e Kolleg-in die " wichtigste Persönlichkeit des deutschen  
     Internet-Business,"  
     [C2 with which INDEF-F colleague-F important personality DEF German  
     Internet-Business  
         [C3 wie der Titel des Preisträgers offiziell hieß ,  
         [C3 as DEF title of prizewinner officially call  
         gleich zum " Internet-König " ernannt hatte , ]  
         now as Internet King name.PAST have.3sg.PAST ]  
 entging allerdings manch-em Kritik-er . ]  
 escape.PAST however many-DAT critic-GEN.PL ]

The fine sense of irony, with which a [female] colleague anointed the "most important personality in the German internet business," as the title of the prize winner is officially called, right away as the "internet king", was however lost on some of the critics. (R Kluender)

LIT

16. Das Schlimmste dabei ist,  
DEF worst of.it be.PRES

[C1 daß all-es,

[C1that all-PL

[C2 was man den gediegen-en Stück-en,

[C2 which one DEF.DAT valuable-PL piece-PL

[C3 die wirklich da sind, ]

[C3 which really that be.PRES ]

so drüber auf-häng-t, ]

over out-hang-PRES ]

um einen Schein von Ganz-heit zu erkünsteln,

around INDEF appearance of complete-ness to create

meistens nur aus ge-färbt-en Lump-en besteht. ]

mostly only of PERF-color-PAST rag-PL consist-PRES ]

“The worst of it is that everything [that they {hang} over the valuable pieces, [that are {really there,} [to  
create the illusion of completeness,] for the most part {consists} of dyed rags.]” (R Kluender)

## SOV

### Japanese

GSD

17.

[C1 Toride kensetsu-no riyuu-wa,  
[C1 fort construction-GEN reason-TOP  
Doitsu-no juujigun kishira-ga ikyouto-no Prusenjin-to  
tatakau-ni-tsure,  
Germany-GEN crusade knights-NOM pagans-GEN Prussians-with fight-DAT-as  
[Toruso-ni sumu  
Truso-in live  
[C2 Prusenjin-ga  
[C2 Prussians-NOM  
[C3 kishidan-ga seifuku-shi-ta ]  
[C3 cavalry-NOM conquest-do-PAST ]  
chi-o saiseifuku-suru-no-o ]  
land-ACC reconquest-do-NMNL-ACC ]  
shirizokeru  
drive.away  
tame-deat-ta.]  
for-COP-PAST]

“The reason for building the fort was to prevent the Prussians in Truso from re-conquering the land that the cavalry conquered as the German crusaders fought with the pagan Prussians.” (M.Takahashi)

18.

[C1 Mata kisha-wa,  
[C1 andreporter-TOP  
[C2 kono jyosei shinjya-ga  
[C2 this female devotee-NOM  
[C3 tonai kinkou-ni-oite Touitsukyoukai-ga soshikiteki-ni  
syoutaigakushi-no  
[C3 in.Tokyo vicinity-DAT-in Unification.Church-NOM organizational-DAT  
hiding.identity-GEN  
ihou kanyuu-ya reikansyouhou-o okonatte-i-ta]  
illegal recruiting-and manipulative.sales-ACC conduct-PROG-PST ]  
group-no ichiin-deat-ta]  
group-GEN a.member-COP-PAST ]  
koto-o kakunin-shite-ori],  
fact-ACC confirm-do-have ]

“The reporter also confirmed that the female devotee was a member of the group where the Unification Church as an organization was recruiting illegally and doing some emotionally manipulative sales in order to hide their identity in the suburbs of Tokyo.” (M.Takahashi)



PUD

19.

[C1 Mata kare-wa,  
[C1 And he-TOP  
[C2 Rogers-ga saikin,  
[C2 Rogers-NOM recently  
[C3 kokyaku-ga data-no shiyuu jyoukyuu-o kanshi-dekiru-yoona],  
[C3 customer-NOM data-GEN usage situation-ACC supervision-can-like]  
atarashii application tool-o doonyu-shi-ta-to]  
new application tool-ACC introduction-do-PAST-COMP]  
shiteki-shi-ta.]  
pointing.out-do-PAST]

“He also pointed out that Rogers recently introduced a new application tool where customers can monitor data usage.” (M.Takahashi)

20.

[C1 Teiki tyouonpa shindan-kara hajimat-ta jitai-wa,  
[C1 regular ultrasound diagnosis-from start-PAST situation-TOP  
[C2 Texas-syuu Plano-no, ninshintyuu-no haha Margaret Boheme-ga,  
[C2 Texas-state Plano-GEN pregnant-GEN mother Margaret Boheme-NOM  
[C3 kanojyo-no onaka-no naka-no ko-ga marena jyoutai-de seizon-no  
[C3 her-GEN stomach-GEN inside-GEN child-NOM rare.condition-with  
survival-GEN  
tameni syujyutu-ga hitsuyou-da-to]  
for surgery-NOM necessary-COP-COMP ]  
tsuger-are-ta]  
tell-PASS-PAST]  
toki-ni fukuzatsuka-shi-ta.]  
time-at becoming.complicated-do-PAST ]

“The situation that started with the regular ultrasound check-ups became complicated when [at the time that] Margaret Boheme, a pregnant mother from Plano, TX, was told that she would need surgery for the survival of her child, who had a rare condition.” (M.Takahashi)

21.

[C1 Kare-wa BBC-noAndrew Marr-nobangumi-de,  
[C1 he-TOP BBC-GEN Andrew Marr-GEN show-at  
[C2 “sousenkyo-wa, sottyoku kuni itte,  
[C2 general.election-TOP honestly say  
[C3 seifu-ga mottomo yari-taku-nai]  
[C3 government-NOM most do-want-NEG  
koto-desu.”]  
thing-COP ]  
to karat-ta.]  
C remark-PAST ]

“In the Andrew Marr Show on BBC, he remarked that ‘honestly speaking, the general election is the last thing that the government wants to do’.” (M.Takahashi)

22.

[C1 Wilkes-wa,  
[C1 Wilkes-TOP

[C2 syominin-ga  
[C2 HoC-NOM

[C3 kare-no syutsuba-ga mukou-de-aruto]

[C3 him-GEN running-NOM invalid-COP-PRES-COMP]

ketsugi-shi jiten kouhosya-no syouri-okouhyou-suru]

decision-do runner-up candidate-GEN victory-ACC disclosure-do]

mae, nido iijyou saisen-shi jyomei-s-are-ta].

before twice more.than reelection-do dismissal-do-PASS-PAST]

"Wilkes got re-elected twice and then dismissed before the House of Commons determined that his run for the office was invalid and declared the victory of the runner-up." (M.Takahashi)

23.

[C1 Roudousya-no chikara kumiai-wa, tou setsumeisyo-no mokuji-ni,  
[C1 laborers-GEN power org.-TOP this manual-GEN index-DAT

[C2 Gillard-shi-wa

[C2 Gillard-Ms.-TOP

[C3 donoyoona soudan-mo jissaini-wa nakat-ta-to]

[C3 whatever consultation-FOC reality-TOP NEG-PAST-COMP

nobe-ta]

state-PAST ]

to yuu bikou-o kuwae-nakat-ta-koto-o hansei-shite-iru].

C say note-ACC add-NEG-PAST-thing-ACC regret-do-PROG ]

"Laborers Power Organization regrets that it did not add the note (stating) that 'Ms. Gillard stated that there was in fact no consultation whatsoever' to the index of this manual." (M.Takahashi)

Japanese: Balanced Corpus of Contemporary Written Japanese

JP1.

[C1 daitouryou-ha

[C1 the president-TOP

doujitsu happyoushita

the.same.day issued

seimei-de

statement-INS

[C2 beikoku-ha

[C2 US-TOP

[C3 obuzaaba-no chii-wo hukume]

[C3 observer-GEN status-OBJ including ]

taiwan-ga daburyueichiou-no katsudou-ni sankasuru koto-wo

Taiwan-SBJ WHO-GEN activity-DAT participate that-OBJ

zennmenteki-ni shijisuru

fully support

to shiteki ]

QUOTE indicate ]

In a statement issued the same day, the President noted that "the United States fully supports Taiwan's participation in WHO activities, including observer status." (A. Masayuki)

JP2.

[C1 seimei-ha

[C1 statement-TOP

houanshomei-he kangei-to kansha-wo hyoumeishi

signing.bill ALL welcome AND gratitude-OBJ express

[C2 beikoku-no shiji-ha

[C2 US-GEN support-TOP

[C3 taiwan-no daburyueichiousannka-heno doryoku-ga sude-ni yuuhou-no rikai-wo eta

koto-wo ]

[C3 Taiwan-GEN WHO.participation-ALL-GEN effort-SBJalready friend-GEN

understanding-OBJ get-PST that-OBJ ]

imisuru ]

mean ]

kongo

from now on

zenryoku-wo agete

full power-OBJ give

kokusaishakai-no

zennmenteki-nasandou-wo

erareruyou

the.international.community-GEN

full

support-OBJ

obtain-PASS

doryokusuru

effort

to nobeteiru ]

QUOTEsay ]

"The statement welcomed and thanked the President for signing the bill and said, "The support of the United States means that Taiwan's efforts (to join WHO) have already gained the understanding of our friends, and we will do our utmost to gain the full support of the international community. " (A. Masayuki)

JP3.

ichibu-no masukomi-ha

some media-TOP

kare-no kikou-wo

agetsurai

his eccentricities-OBJ

criticize

[C2 kare-ga

[C2 he-SBJ

[C3 asa-ha

nijuu ichi seikino

ekosozai

nado-to

[C3 hemp-TOP the 21st century-GEN

ecofriendly.material etc-QUOTE

hanashiteita koto-kara ]

talk-PST that ]

taima-wo

sutteitanodehanaika nado-to

marijuana-OBJ smoke-PST etc-OBJ

jasui-wo

moto-ni houjiteita

false.rumors-OBJ

based-on

report-PST

"Some media outlets, criticizing his eccentricities, reported on the basis of rumors that he may have been smoking marijuana, because he had called hemp an "eco-friendly material for the 21st century."(A. Masayuki)

JP4.

[C1 iesu-ha

[C1 Jesus-TOP

hakkiri itteoku

clearly say

[C2 anata-ha koNya

[C2 you-TOP tonight

[C3 tori-ga nakumae-ni ]

[C3 rooster-SBJ before crowing ]

sando

three times

[C3-b watashi-no koto-woshiranai-to ]

[C3-b me OBJ not know-QUOTE ]

iudarou ]

will say ]

to tsumetaku iimasu ]

QUOTE coldly say ]

Jesus said coldly: "I tell you, tonight before the rooster crows, you will say three times that you do not know me." (Matthew 26:34)(A. Masayuki)

JP5.

[C1 kono kitei-ha

[C1 this provision-TOP

saimusha-ga niNi-ni risoku-wo shiharatta

the debtor-SBJ voluntarily interest-OBJ pay-PST

[C2 gyousha-ga saimusha-ni

[C2 the business operator-SBJ the debtor-DAT

[C3 hitsuyoujikou-ga kakareta ]

[C3 the necessary information-SBJ written ]

keiyakushomeN-ya uketorishousho-wo koushushiteiru ]

contract OR receipt-OBJ provide ]

nado-no youken-wo mitaseba

etc.-GEN the requirements-OBJ satisfied

gureezoon-nitsuiteno risokuhensai-wo yuukou-to minashiteiru ]

on gray zone interest rates interest repayment-OBJ valid-QUOTE deem ]

"This provision deems interest repayment on gray-zone interest rates to be valid if (1) the debtor voluntarily pays the interest, (2) the firm provides the debtor with a contract or receipt wherein the necessary information is written and (3) other requirements are satisfied. "(A. Masayuki)

JP6.

wafuku-ni kuro-no kawatebukuro-toiu onajimi-no yosooi-de toujoushita  
 Japanese.clothes-DAT black leather gloves familiar cover up-DAT appear-PST

[C1 Kyougokushi-ha

[C1 Mr. Kyogoku-TOP

[C2-1 kaidan-niha

[C2-1 ghost.story-DAT-TOP

[C3 nihonjin-ga tuchikattekita

[C3 Japanese-SBJ cultivate-PST

bunka-no shinzui-ga haNeisareteori

culture-GEN essence-SBJ reflect-PASS

bungei-no oudouda-to omotteiru ]

literature-GEN royal.road-COP-QUOTE think ]

[C2-2 sono mattan-ni turanaru koto-ga dekireba-to

[C2-2 that end-DAT stand.in.a.row that-SBJ can do-SBJV-QUOTE

omotte kaita ]

think write-PST ]

[C2-3 jushou-ha nagai nihon bunka-gA attekoso-no monode

[C2-3 winning.award-TOP long Japanese culture-SBJ exist-GEN

that-DAT

watashi-no yakuwarinado ke-no sakihodo-mo nai ]

my role etc.hair-GEN end-TOP be.not ]

to nobeta ]

QUOTESay-PST ]

"Mr. Kyogoku, who appeared in traditional Japanese clothing and black leather gloves, said, "I believe that ghost stories reflect the essence of the culture that the Japanese have cultivated and are a royal road to literature and art.I wrote this book in the hope that I could be a part of the end of that tradition. The award is a testament to the long history of Japanese culture, and I have no part to play in it [lit. not a hair]." " (A. Masayuki)

JP7.

shousenkyoku-hireidaihyouheiritsusei-no hireidaihyou-ha

Mixed.member-proportional.representation-GEN proportional.representation-TOP

[ kakutou-ga

[ each.party-SBJ

kono hito-ha kuni-no yaku-ni tatsu

this person-TOP nation-GEN useful useful

nihon-no seiji-no tame-ni hitsuyou-na hitoda-to

Japanese politics-GEN for necessary person-COP-QUOTE

itte ]

say ]

kakukai-kara nenreiseigennado nashi-de kouhoshameibo-wo tsukuri kokuminni

teijisurutoiuno-ga

from various fields age limit etc. without candidate list-OBJ make citizen-DAT do

presentation-SBJ

arubeki sugatada

ideal situation-COP

"Proportional representation in a system of mixed member proportional representation, in which each party says "this person is useful for the people of this country and necessary for Japanese politics," and in which a list of candidates from various fields with no age limits is presented to the citizens, is the ideal situation." (A. Masayuki)

JP8.

[C1 Nihonhamu-ha

[C1 Nippon.Ham-TOP

sakuki tochiu-de Gyaraado gen Yokohama ga chuunichi-wo taidanshita  
sai

last season in the middle Garrard currently Y.-SBJ Ch.-OBJ retire-PST when

[C2 hirimankantokuha

[C2 Head Coach Hillman-TOP

[C3 tateyama-ga osae-ni teichakushiteiru koto-kara ]

[C3 Tateyama-SBJ closer-DAT fixed that-since ]

kakutoku-ni kyoomi-wo shimesazu ]

hiring-DAT interest-OBJ not indicate ]

miokutta keii-ga aru ]

passed story exist ]

"Nippon Ham (baseball team) has a history of not being involved in this: when Garrard (now at Yokohama) left Chunichi in the middle of last season, manager Hillman was not interested in hiring Tateyama because he was already established as an infielder."(A. Masayuki)

JP9.

Hatoyamadaihyou-ha

Hatoyama (party) representative-TOP

onzonsurunodehanaika [C2-1 Koizumishushou-ha jibun-no chikara-wo tanposuru tame-ni kaisanken-wo

preserved [C2-1 prime.minister K.-TOP own power-OBJ secure for the right to dissolve-OBJ be

to hatsugenshita koto-ga

QUOTE say-PST that-SBJ

Hatoyama-ha yowaki

Hatoyama-TOP coward

to houdousaretatoshi ]

QUOTE report-PASS ]

[C2-2 Koizumininki-ni aorarete Hatoyama-ha ikishouchinshiteiru-to  
popularity of K.-DAT incite-PASS Hatoyama-TOP be depressed-QUOTE

iwareru-ga

be said

kesshite sonnakoto-ha nai ]

never such thing-TOP is not ]

[C2-3 watashitachi Minshutou-ha

[C2-3 we Democratic Party-TOP

[C3 kibishikutemohayaku sousenkyo-wo yarubekida-to ]

[C3 even if severe early general election-OBJ should do ]

omotteiru ]

think ]

to kyouchoushita

QUOTE emphasize-PST

Hatoyama said:

that his comment that "Prime Minister Koizumi may preserve the right to dissolve the Diet in order to guarantee his own power" was reported as "Hatoyama is a coward"

that "the claim that Hatoyama is depressed because of Koizumi's popularity, but this is not true"

And: "We, the Democratic Party of Japan, believe that we should hold a general election as soon as possible, even if it is hard." (A. Masayuki)

JP10.

kaiunkankeisha-ha

shipping industry personnel-TOP

ooku-no kaiungyousha-ga koureikashita nihonjinkanbuseNin-to firipinnado-no wakai gaikokujinseNintoiu  
kousei-ni natteiru

many shipping company-SBJ aged Jp. officer sailor AND Ph.etc.-GEN young foreign sailors

personnel composition-DAT become

[C2 mondai-ha

[C2 problem-TOP

[C3 nihonjinsenchoutachi-ga intaishita ]

[C3 Japanese captains-SBJ retire-PST ]

tokida ]

when-COP ]

shitekisuru

point out

"A shipping industry insider noted, "Many shipping companies are made up of aging Japanese executives and young foreign seafarers from the Philippines and other countries. The problem is when the Japanese captains retire." (A. Masayuki)

JP11.

[C1 mata chuutoujaanarisuto-no fujiwarakazuhikosan(60)-ha

[C1 Also middle east journalist-GEN Mr. Kazuhiko Fujiwara (60 years old)-TOP

[C2 irakujiNippannitotte-ha

[C2 normal Iraqi-TOP

[C3 huseinmotodaitouryou-ga ikiteireba

[C3 former president Hussein-SBJ alive-SBJV

itsuka seikenni odottekurukamoshirenai

someday power-DAT may come back

kowasa-ga attaga

fear-SBJ exist-PST

kousokusareta koto-de

restrained that-DAT

andokan-ga hirogaru ]

sense of relief-SBJ spread ]

korosazu-ni kousokushiata koto-ha

without killing restrain that-TOP

motodaitouryou-ga shinkakukasarenai koto-ni

the former president-SBJ not be deified that-DAT

tsunagari

lead

imi-ha ookii

meaning-TOP large

to hanashita ]

QUOTEtalk-PST ]

"Kazuhiko Fujiwara, 60, a Middle East journalist, said, "Iraqis in general were afraid that former President Hussein might one day return to power if he were still alive, but the fact that he was detained has spread a sense of relief. The fact that he was detained without killing him is very meaningful because it means that the former president will not be deified." (A. Masayuki)

JP12.

[C1 isuraeru-no sharonshushou-ha

[C1 Israeli Prime Minister Sharon-TOP

sanjuunichiyoru terebienzetsushi

on 31st evening make a television speech

[C2 isuraeru-ha

[C2 Israel-TOP

[C3 tero-tono sensoujoutai-ni aru ]

[C3 on terrorism state of war-DAT exist ]

to genmei ]

QUOTEdeclare ]

[C2b terorizumu-ha

[C2b terrorism-TOP

[C3b tousei-ga toreteori ]

[C3b control-SBJ take ]

hitori-no otoko-nimichibikareteiru ]

one person-GEN man-DAT be led ]

to arafatogichou-wo nazashishita

QUOTEPresident Arafat-OBJ indicate

"In a televised speech on the evening of March 31, Israeli Prime Minister Ariel Sharon declared that Israel is "at war" with terrorism, and named Arafat as a terrorist leader" (A. Masayuki)

JP13.

[C1 shushou-ha

[C1 the president-TOP

yuubinjigyou-ni minkan-ga sannnyuusuru sai-ni

postal.business-DAT private.sector-SBJ enter when

[C2 imamade kyuuyuuseishou-ga

[C2 until now former.MPT-SBJ

[C3 kurejittokaado-ha shinsho-da]

[C3 credi.card-SBJ letter-COP]

toitte jamashitarishinaiyou-ni ]

QUOTEso as not to disturb ]

[C2-2 kyokaseinari todokedeseinarinisuru

[C2-2 permission system notification system

baai-ha

case-TOP

shikkari-to minkan-ga sannnyuudekiruyouna

firmly private sector-SBJ enter

kouhei-na sochi-ga hitsuyou ]

fair measure-SBJ necessary ]

[C2-3 souiuten-mo kangaete houan-wo tsukuruyouni

[C2-3 that point-TOP think bill-OBJ make

jikan-ni shiji-shita ]

undersecretary-DAT instruct-PST ]

to nobeta ]

QUOTETalk-PST ]

"The Pres said, "When the private sector enters the postal service, the former Ministry of Posts and Telecommunications should not interfere by saying that credit cards are letters, and if (in the case that?) a permit system or notification system is adopted, fair measures must be taken to allow the private sector to enter. I have instructed the Undersecretary to draft the bill with this point. "

(A. Masayuki)



JP14.

[C1 doutai-ha

[C1 the team-TOP

[C2 XXXyougishara-ga

[C2 suspect.XXX.and.coworkers-SBJ

[C3 kaigai-de hakkousareta

[C3 overseas issued

kaado-no baai-ha chekku-ga amai koto-wo ]

card-GEN case-TOP check-SBJ lax that-OBJ ]

akuyoushita-to ]

exploit-PST ]

miteiru ]

imagine ]

"The team believes that suspect X and their coworkers took advantage of the fact that credit cards issued overseas are subject to lax security checks." (A. Masayuki)

JP15.

[C1 jidoushayouhinoote-no ieroohatto-ha

[C1 auto parts sales major-GEN Yellowhat-TOP

supootukaanado-no kasutamaizu-wo shiteita

sports car etc.-GEN customization-OBJ do-PST

[C2 wakai hito-ga

[C2 young people-SBJ

[C3 kekkoushite kodomo-ga dekita-ato

[C3 marry child-SBJ after having

miniban-ni norikaetekaramo tsudukeru ]

minivan-DAT change continue ]

koto-ga ooinodeha ]

that-SBJ be large number ]

to hanasu ]

QUOTEtalk ]

"Yellow Hat, a major auto accessory sales company, says, "Many people who used to customize sports cars and other vehicles, after they get married and have kids, switch to minivans and continue [doing so]."  
" (A. Masayuki)

JP16.

[C1 korenitaishite tanakasan-ha

[C1 on the contrary Ms./Mr. Tanaka-TOP

menjosuru-to itta koto-ha nai

exempt-QUOTESaid that-TOP not exist (never said)

[C2 oya-ga kashitatoi hyakumaNen-ha

[C2 parents-SBJ lent one million yen-TOP

[C3 jibun-ga oya-ni tanonde ]

[C3 self-SBJ parents-DAT ask ]

nakajimasan-ni watashitemorattanodeatte ]

Ms./Mr. Nakajima-DAT give-PST it to ]

kashitano-ha jibun

who lent it I

to hanronshiteimasu ]

QUOTEobject ]

"Tanaka objected, "I never said I would exempt myself. The one million yen that my parents loaned me (when I asked them for it) was given to Nakajima, and the one who loaned it to him was me." (A. Masayuki)

JP17.

[C1 hansei-wo tsudutta  
half a lifetime-OBJ written  
taicho"ajiatokuden"-wo honyaku-shita  
book "Asia special telegram"-OBJ translate-PST  
Yajima Midori-ha  
Yajima Midori-TOP  
daisan-no - no shuppanji  
third - GEN when published  
deeta-no ue-deha ude-ni nihon-ha sekaisaNi-no keizaitaikoku-ni  
natteita-nnoni  
data-GEN on already Japan-TOP third.in.world-GEN superpower-DATbecome, but  
[C2a naiseiteki-na nihonjin-ha jibun-de  
[C2a introspective Japanese-TOP by self  
Nihon-ha mada sengo  
Japan-TOP yet postwar  
to omotteita ]  
QUOTEthink-PST ]  
[C2b sore-woGiran-san-ga jishintappuri-ni  
[C2b that-OBJ Ms./Mr. Gillan-SBJ confidently  
[C3b nihon-ha taikoku ]  
[C3b Japan-TOP major country ]  
to hakkiri kaita  
QUOTEclearly write-PST  
rekishitekiigi-ha ookii ]  
historical significance-TOP large ]  
to kataru  
QUOTEtalk ]

"Midori Yajima, translator of the major book "Asia Tokuden," which chronicles Gillan's life in Japan, says, "At the time of the publication of 'The Third -' Japan was already the third largest economy in the world according to the data, but introspective Japanese people thought Japan was still postwar. But the fact that Mr. Gillan wrote confidently and clearly that Japan was a great power, is of great historical significance."

JP18.

[C1 Ichiko nitotte naniyori-mo tsurai koto-ha  
[C1 for Ichiko more than anything tough that-TOP  
[C2 Oosugi-ga Ichiko-no menzen-de  
[c2 Oosugi-SBJ Ichiko-GEN in front of her face  
[C3a anta-ha rikai-ga nai ]  
[C3a you-TOP understanding-SBJ not exist ]  
[C3b Ito-ha yoku rikaishiteiru ]  
[C3b Ito-SBJ well be understanding ]  
to choushoushinagara iu ]  
QUOTEmocking say ]  
kotodatta ]  
that-COP-PST. ]  
The worst for Ichiko was when Osugi mocked her to her face, saying: "You don't understand. Ito understands you very well."

JP19.

[C1 Neruson-shi-ha

[C1 Ms./Mr. Nelson-TOP

[C2 yuushuu-na hatsumei-mo

[C2 great invention-TOP

[c3 TLO-ga nakereba ]

[C3 TLO-SBJ not exist-SBJV ]

tada-no kenkyuuronbuntoshite umoreteita ]

just as a research paper be buried ]

to shitekisuru ]

QUOTEpoint out ]

Nelson points out that "if TLO didn't exist, excellent inventions would have been buried as mere research papers."

## Korean

GSD

24.

[C1 Yununhyey-nun

[C1 Y.-TOP

[C2 "kipwukum-i centaltoyl sonyetul-i

[C2 donations-NOM be.delivered girls-NOM

[C3 seysang-ey-nun ilehkey" ttattushan salamtul-i manhta]-nun kel ]

[C3 world-LOC-TOP like kind people-NOM many-NMNL BOUND.NOUN ]

al-ko te khun huymang-ul kacessumyen ]

know-CONJ more big hope-ACC have do-COMP ]

ha-nun palam-i-ta"ko

wish-be-DEC"COMP

malhayss-ko,]

said-CONJ(AND) ]...

Y. said that "(I) wish that the girls who will receive the donations would know that there are many kind people in the world and have more hope", (H. Shin)

25.

[C1 lentupulaytu taypyenin-un

[C1 L.B. (NAME) spokesperson-TOP

[C2 choykun suweyteyn swusatay-ka

[C2 recently Sweden investigators-NOM

[C3 ku-ka thekhi hangkongs-eyse ilha-ko iss-ta]nun

[C3 he-NOM Turkey airline-LOC work-COMP be-PST-NMNL ]

ceypo-nun pat-ass-tako ]

information-TOP receive-PST-COMP

malhay-ss-ta.]

say-PST-DEC

"Spokesperson L.B. said that the Swedish investigating team recently received information that he is working at the Turkish airline." (H. Shin)

26.

[C1 Ilpon Teyilli.suphochu-nun 30il i-kathun Okhata kamtok-uy mal-ul cenha-myense

[C1 Japan Daily.Sports-TOP 30th this-like Okada director-of words-ACC deliver-while

[C2 'Okhata kamtok-un

[C2 'Okada director-TOP

[C3 Pakchanho-wa Isungyep-i thim-nay hwahak-panung-ul ilukhy-e

[C3 P.-and I.-NOM team-inside chemistry-reaction-ACC bring-and

thim-ul hwalsenghwasikhi-I kes-ul ]

team-ACC revitalize-NMNL BOUND.NOUN-ACC ]

kitayha-ko iss-ta' ko ]

expect-COMP be-DEC COMP ]

potohay-ss-ta.]

report-PST-DEC]

"Japan Daily Sports on 30th delivered director Okada's words and reported that 'director Okada is expecting that P. and I. will bring a chemical reaction and revitalize the team'." (H. Shin)

27.

[C1 i-nun

[C1 this-TOP

[C2 imi cinan 3wel mal pelak opama taythonglyeng-I

[C2 already last March end Barak Obama president-NOM

[C3 swusip nyen-kan wenyu-wa chenyenkasu yucen kaypal-I kumci.toe-ss-te-n ]

[C3 dozens year-in oil-and gas field exploration-NOM

prohibit.become-PST-RT-MD ]

tayseyang yenan-kwa meygsikhoman tongpwu allaysukha pwukpwu hayan tung-ey

Atlantic coast-and gulf.of.Mexico east Alaska north coast etc.-on

tayhay yucen thamsa-wa sichwu-lul heyong ha-ess-te-n ]

concern oil field exploration-and drilling-ACC allow-do-PST-RT-MD ]

cochi-lul twue tal man-ey twuicip-nu-n kes-i-ta. ]

action-ACC a couple month only-in overturn-ID-MD k-COP-DECL ]

'This is an overturn, after only a couple of months, of President Barack Obama's action at the end of March: allowing oil field exploration and drilling off the Atlantic coast, the eastern Gulf of Mexico, the northern coast of Alaska, etc., where oil and natural gas field exploitation has been prohibited for several decades.' (S. Jang)

28.

[C1 Nyuyogthaimsu-nun

[C1 NYT-TOP

kini mangmyengca chwulsin hothel yecongepwen-i-n

guinea fugitive from hotel waitress-COP-MD

[C2 phihay yeseng-I

[C2 victim female-NOM

[C3 Khan cen chongcay-uy thwuswuk cikhwu etten itug-ul chwuiha-I swu

[C3 Khan former director-of stay right after what gain-ACC get-be able

iss-ul-ci]

to-PROS-NM ]

kongmo.ha-n ]

plot.do-MD ]

cenghwang-ul kemchal-I phochag-ha-ess-ta-ko

circumstance-ACC prosecution-NOM catch.do-PST-DECL-QT

poto.ha-ess-up-ni-ta. ]

report.do-PST-AH-ID-DECL ]

'New York Times reported that the prosecution caught the circumstantial evidence that the female victim, who was a Guinea fugitive hotel waitress, planned what benefits she'd be able to gain right after the former director Kahn's stay.' (S. Jang)

29.

[C1 Co Myeng-lay tankwuktay kyoswu-nun

[C1 Cho Myeng-rae Dankook Univ. professor-TOP

“cengpwu-ka cwuthayk-ul mayip.ha-e Censey seyipca-wa cipwun-ul celpanssig nanwue

kac-nun

government-NOM house-ACC buy-CONJ Lease tenant-with stake-ACC halves split

have-MD

[C2 cipwunhyengcwuthayk]-un

[C2 stakeholding housing]-TOP

[C3 soywukwen-ul inceng.ha-myense cwuke anceng-ul kkoe.ha-l swu iss-nun]

[C3 Ownership-ACC acknowledge.do-CONJ housing stability-ACC attempt.do-be able

to-MD

pangan”]-i-

way-COP-CONJ

“kongkongseng-ul hwagbo.ha-ci anh-un chay kwyuce-lul wanhwa.ha-ko Seceyciwen-ul

kanghwa.ha-lye-nun

publicity-ACC secure.do-NM NEG-as regulation-ACC mitigate.do-CONJ Tax support-ACC

reinforce.do-INT-NM

cengchayg]-un kyelkwug sangwikyecheng-kwa Koka cwuthayk poyuca-tul-ekey-man

hyethayg-l tolaka-ko

policy-TOP eventually upper class-and High value house holders-PL-to-only benefit-NOM

go-CONJ

Silhyoseng-un tteleci-l swu iss-ta”-ko]

Effectiveness-TOP fall-be able to-DECL-QT

cicek.ha.-ess-ta.]

point out.do-PST-DECL

‘Prof. Myeong-rae Cho (Dankook Univ.) pointed out that “stakeholding housing, which is that the government buys houses and shares a half of the stakes with lease tenants, is a way that means for housing stability while acknowledging ownerships,” and “as for a policy that intends to mitigate regulations and reinforce tax supports without securing the publicity, eventually, its benefits will go only to high-value house holders and its effectiveness can fall.”’ (S. Jang)

30.

[C1 Sewulhayngcengpepwen hayngceng14pwu(cinchangswu pwucangphansa)-nun

[C1 Seoul administrative court administrative 14 dept.(Chin Changsu head judge)-TOP

[C2 Sengkyunkwantayhagkyo-ka

[C2 Sungkyunkwan University-NOM

[C3-1 “kyooe kiswugsa kenmwul-ey tayha-n Nongechonthugpyelsey pwukwa-nun]

[C3-1 “off campus dorm building-be about-NM Special Rural Dev’t Tax impose-TOP ]

[C3-2 Conglo · sengpwukkwuchengcang-ul sangtay-lo ceki.ha-n pwutang.ha-ta-mye ]

[C3-2 Jongno · Sungbuk district head-ACC against-as file.do-NMunjust.do-DECL-CONJ

hayngcengsosong-eyse Wenkosungsophankyel-ul nayli-ess-ta-ko ]

administrative.litigation-in Plaintiff’s win decision-ACC rule-PST-DECL-QT ]

27il palghye-ss-ta ]

27th clarify-PST-DECL ]

‘Dept. of Administrative14 of Seoul Administrative court (Chin Changsu Head Judge) clarified on the 27th that (they) ruled a decision in favor of the plaintiff in the administrative litigation that Sungkyunkwan Univ. filed against the head of Jongno · Sungbuk district (which stated) that “imposing Special Rural Development Tax onto off-campus buildings is unjust.”’ (S. Jang)

31.

[C1 Taumkhaphey ‘myenchaygcakhullep’-uy wunyengca hecin(43yo)-ssi-nun

[C1 Daum Café ‘the exempted club’-of manager Hur Jin (43yo)-Ms/Mr-TOP

[C2 “myenchaygca-nun  
 [C2 “The exempted-TOP  
     [C3 kongkongcengpo-la-nun kilog-l 5nyen tongan(congcen 7nyen)-Ina nama iss-e ]  
     [C3 public info-called-NM record-NOM 5 yrs during(previously 7 yrs) as remain  
 be-because]  
     I kikan tongan amwulen kumyunghwaltong-ul ha-l swu eps-ta”-mye ]  
     this period during any financial activity-ACC do-not be able to-DECL-CONJ ]  
 [C2-B “i-nun  
 [C2-B this-TOP  
         pepwen-eyse myenchayg-ul hay cwu-n  
         court-at exemption-ACC do give-NMNL  
     [C3-B chwuici-lul Cengpwu-wa kumyungkikwan-l mwusi.ha-nun  
     [C3-B purpose-ACC Government-and financial institution-NOM ignore.do-NMNL  
     kes-i-lako ]  
     KES-COP-QT ]  
 mal.ha-ess-ta.]  
 say.do-PST-DECL.

‘Ms/Mr. Hur Jin (43yo), the manager of the Daum Café ‘The Exempted Club’, said “the exempted people cannot do any financial activities for 5 years (previously 7 years) because the record (so-called public information) remains for that period of time,” and “this is the government and financial institutions ignoring the purpose that the court gave the exemptions.’ (S. Jang)

32.

[C1 Pai uiwen-un  
 [C1 Bayh senator-TOP  
     inal wesingthenDC-eyse kaymag-toe-n  
     this.day Washington DC-in commence-become-NMNL  
 mi-isulaelkongkongcengchaygwuiwenhoi(AIPAC)yenlyechonghoi-uy Lawuntutheyipul tholon-eyse  
 U.S-American Israel Public Affairs Committee annual.meeting-of Roundtable discussion-at  
     [C2 wuli-nun  
     [C2 we-TOP  
         ilan cengkwen-ey Thakyeg-ul cwu-l swu iss-nun]  
         Iran administration-against blow-ACC give-be able to-NMNL  
     [C3 kongkyekcek-i-n ceycay-lul kyesog hay-naka-l ]  
     [C3 aggressive-COP-MD sanction-ACC continuously do-go-NMNL ]  
     philyo-]ka lss-ciman,]  
     need-NOM Be-though  
         ceycay-nun cal mek-hi-ci anh-ul]  
         sanction-TOP well work-PASS-NMNL NEG-NMNL  
     kes]-i-lamye]  
     KES-COP-CONJ  
     i-kathi palghi-ess-ta-ko ]  
     this-like clarify-PST-DECL-QT ]  
 mi enlon-tul-l 22il cen.ha-ess-ta.  
 U.S. press-PL-NOM 22nd report.do-PST-DECL

‘The press in the U.S. reported on the 22nd that, at the roundtable discussion at the annual meeting of the US-AIPAC, which was commenced in Washington DC on the same day, Sen. Bayh clarified as this, such that “although we need to continue aggressive sanctions that can give a blow against Iran administration, the sanctions will not work well.”’ (S. Jang)

33.

[C1 keysuthumeythuligsu-uy CEO pulaien paleys-un  
 [C1 Guest Metrics-of CEO Brian Barrett-TOP  
 [C2 "wuli-nun  
 [C2 "we-TOP  
 [C3 kokayg-tul-l encey eti-se-na teyithe-ey cepkun.ha-e  
 [C3 customer-PL-NOM here when-at-ever data-to access.do-CONJ  
 cenlyagceg-i-n picunisu uisakyelceng-ul nayli-l swu iss-nun]  
 strategic-COP-MD business decision making-ACC take-be able to-NM  
 Kanglyeg.ha-n mopail BI app-ul cekong.ha-ko iss-ta"-ko]  
 powerful.do-MD mobile BI app-ACC provide.do-PROG-DECL-QT ]  
 mal.ha-ess-ta.]  
 say.do-PST-DECL ]

'Brian Barrett, the CEO of Guest Metrics, said "we are providing a powerful mobile BI app in which customers can access to their data regardless of time and place and take a strategic business decision making."' (S. Jang)

34.

[C1 ie Kim uiwen-un  
 [C1 subsequently Kim congressperson-TOP  
 [C2 this-TOP  
 [C2 i-nun  
 [C3 yeya citopwu, chengwatay, cengpwu motwu-ka kwukhoi-lul palo  
 seywu-ko  
 [C3 party leaders, Blue.House, gov't all-NOM Nat'l Assembly-ACC right  
 set-CONJ  
 mincwucwuuy-uy sengswug-ul uyhay ta kathi komin.hay poca]]]-nun]  
 democracy-of maturity-ACC for all together be concerned let's-NM  
 kankog.ha-n mwunceyceyki-lako ]  
 desperate.be-MD problem-posing-QT ]  
 Tespwuthye-ss-ta ]  
 add-PST-DECL ]

'Subsequently, congressperson Kim added "this is a desperate problem-posing that suggests all the leaders of the ruling and the opposition parties, the Blue House, and the government need to set the National Assembly right and all together to be concerned for the maturity of democracy."' (S. Jang)



35.

[C1 i ceyto-nun  
[C1 this policy-TOP

hyeng-I cwug-umyen  
older.brother-NOM die-if  
caysan-ul hyengswu-ka mwullyepatkey toe-ko,  
possession-ACC older.brother's.wife-NOM inherit become-conj  
hyengswu-ka  
older.brother's.wife-NOM  
[C3 hyelcog-i ani-n ]  
[C3 kin-be NEG-MD ]  
talun salam-kwa honin.hakey toe-myen  
other-MD person-with marry.do become-if  
wenlay hyelcog-uy kes-i-ess-te-n  
originally kin-of thing-COP-PST-RT-NMNL  
caysan-I hyelcog-uy pakkath-ulo yuchwul.hakey toe-m-ul  
possession-NOM kin-of outside-to outflow.do become-NMNL-ACC  
yemlye.ha-ye  
concern.do-because  
[C2 natana-n]  
[C2 come out-NMNL ]  
ceyto]-i-ta.]  
policy-COP-DECL

'This policy is a policy that came out because of concern about [this situation: ], if an older brother dies, when (his) possessions are inherited by his wife, if the wife marries another person who is not part of the family, the possessions (which originally belong to family members) are distributed outside the family.'(S. Jang)

36.

[C1 Songtayhyen LG cenca C&C saeppwucang(pwusacang)-un  
[C1 Song Daehyun LG electronics C&C division head(vice president)-TOP  
othomwuping kiswul-ul cegyong.ha-n]  
auto.moving technology-ACC apply.do-MD  
[C2 Lopossaikhing]-un  
[C2 Robocyking-TOP  
[C3 chengsoki sayong kocengkwanchem-ul kkay-mye  
[C3 vacuum cleaner use stereotype-ACC break-CONJ  
chengso hayngtong-kkaci-tohoigkiceg-ulo pakkwu-l swu iss-nun]  
cleaning behavior-to-too groundbreaking-as change-be able to-MD]  
chemtan ceyphwum]-ulo ]  
cutting edge product-as ]  
cisogceg-i-n kiswul hyegsin-ulo chengsoki  
continuous-COP-MD technology innovation-by vacuum cleaner  
sicang sentwu cali-lul ieka-l kes]-i-lako]  
market leader position-ACC maintain-PROS KES-COP-QT  
Mal.ha-ess-ta.]  
say.do-PST-DECL

'Song Daehyun, C&C division head (vice president) of LG Electronics, said "Robocyking, which adopted auto-moving technology, is a cutting-edge product that can break the stereotypes of using vacuum cleaners and can dramatically change cleaning behaviors, and (Robocyking/we) will maintain the (our) position as the leader of vacuum cleaner market through continuous technology innovation.'" (S. Jang)

37.

[C1 i-ey           aphse           kamsawen-un  
[C1 this-DAT before           the.Board.of.Audit.and.Inspection-TOP  
[C2 kwenyengthayk yengyangkwun-swu-ka  
[C2 Kwon.Youngtaeg Yeongyang.County-headman-NOM  
[C3 casin-i                           —<sup>1</sup>           taycwucwu-lo           iss-nun]  
[C3 himself-NOM                   large.stockholder-as           be-ADN ]  
kenselsa<sub>1</sub>-ey           swusip-ye ken-uy           kongsa-lul           swuuykyeyyak-ulo  
construction.company-to dozens-about cases-gen construction.project-acc private.contract-as  
palcwuha-ycwu-ko, ]  
hire-do.a.favor-and ]  
ku           tayka-lo           swu-ek                           wen-ul pat-ass-ta-nun  
that           incentive-as           several-hundred.million won-acc receive-pst-dec-adn  
nayyong-uy           kamsa.kyelkwa-lul           palphyoha-yss-supnita. ]  
message-gen           inspection.result-acc           announce-pst-dec ]

'Prior to this, the Board of Audit and Inspection announced the result of inspection, the message that Youngtaeg Kwon, the Headman of Yeongyang County, had been hiring, for its benefit, a construction company where he was a large stakeholder for dozens of construction projects on a private contract, and he received several hundred million South Korea won as the incentive.' (D. Jung)

38.

[C1 sinmwun-un           peyicing           han oykyo           sosikthong-uy mal-ul           pilli-e  
newspaper-TOP           Beijing one           diplomacy           source-GEN           speech-ACC           quote-COMP  
[C2 "pwukhan-i  
[C2 North.Korea-NOM  
kim wiwencang samang-kwa kwanlyenha-n  
Kim Supreme.Leader           death-with           relate-ADN  
somwun-i           tteto-nun]           kes-ul mak]-ki           wihay]  
rumor-NOM           go.around           KES-ACC prevent-NZ           in.order.to  
[C3 phyengyang           simin-i oykwukin-kwa cepchokha-nun] kes-ul  
[C3 Pyongyang           citizen-NOM foreigner-with           contact-ADN KES-ACC  
kkeli-ko.iss-ta"]-ko  
taboo-PRG-DEC-COMP

cicekha-yss-ta].

Indicate-PST-DEC ]

'A newspaper indicated, quoting a diplomacy source in Beijing, "North Korea is tabooing for the citizens of Pyongyang to interact with foreigners, in order to prevent for the rumor concerning the death of the Supreme Leader Kim to spread." (D.Jung)

39.

[C1 kum-thamsa sangphwum-ul wunyengha-ko.iss-nun yehayngepchey<sub>1</sub>-uy han  
 pwusacang-un  
 [C1 gold-panning program-ACC conduct-PRG-ADN travel.company-GEN one  
 vice.president-TOP  
 [C2 "kwake-ey-nun kum-thamsa-ka  
 [C2 past-in-TOP gold-probing-NOM  
 [C3 nai.tu-n salam-tul-uy tanchey yehayng-i-n]  
 [C3 be.old-ADN people-PL-GEN group tour-be-ADN ]  
 kyengwu-ka manh-ass]-ciman  
 case-NOM be.many-PST-but  
 choykune-nun celmuni-tul-i manh-i nathana-n-ta"-mye]  
 recently-TOP young.people-PL-NOM be.many-ADVZ show.up-PRS-DEC-while.saying ]  
 "cwutoy-n iyu-nun kum kakyek ttaymwun-ulo]  
 be.major-ADN reason-TOP gold price because.of-COMP  
 sayngkaktoy-n-ta"-ko]  
 come.to.think-PRS-DEC-COMP  
 malha-yss-ta.]  
 say-PST-DEC]

'A vice president of a travel company that conducts a gold-panning tour program said, while saying "in the past, a gold-panning tour was mostly the case that it is a group tour of elderly people, but in these days, young people show up in large numbers", "we came to consider the price of gold as the major reason". (D. Jung)

40.

[C1 pyengwen kwankyeyca-nun  
 [C1 hospital officials-TOP  
 [C2 "i-pen hyepyak-un  
 [C2 this-time agreement-top  
 [C3 kyengkito sopang-caynan-ponpwu-ka wenkyek-yengsang  
 [C3 Kyungkido firefighting-natural.disaster-headquarter-NOM remote-image  
 uylyo-cito sisuthey-m-ul kwuchwukha]-m-ey.ttala  
 medical-guidance system-ACC establish-NZ-due.to  
 silsi-toy-ess-ta"-myense]  
 effectuate-PAS-PST-DEC-COMP(while.saying)  
 "ansan-si sanglokkwu-eyse-nun  
 Ansan-city Sangnokgu-in-TOP  
 —<sub>1</sub> kongkong-uylyo-kikwan-i-n  
 public-medical-organization-be-ADN  
 ansan-cwungang-pyengwen<sub>1</sub>-i yuilhakey phoham-twa-yss-ta"-ko]  
 Ansan-Jungang-Hospital-NOM solely include-PAS-PST-DEC-COMP]  
 cenha-yss-ta.]  
 tell-PST-DEC ]

'An official from the hospital said, while saying "this agreement was effectuated due to (the fact) that the Kyungkido Fire & Disaster Headquarters established a remote-image medical guidance system", "as to Sangnokgu in Ansan, the Ansan Jungang Hospital, which is a government-run medical organization, was solely included (in the system)".' (D. Jung)

41.  
 [C1 24il soihyen-uy sosoksa Khiisuthu chuk-un  
 [C124-day So.E-Hyun-GEN agency Keyest side-TOP  
 [C2 "soihyen-uy namcachinkwu-nun hyencay  
 [C2 So.E-Hyun-GEN boyfriend-TOP now  
 [C3 yenyeykyey-wa-nun kwankyey eps-nun]  
 [C3 entertainment.world-with-TOP relation not.exist-ADN ]  
 il,-ey congsa cwung"-ila]-mye]  
 business-in engage under-COMP- COMP(while.saying)  
 "ilpanin-i-la]  
 non.celebrity-be-because  
 [C6 caseyha-n sinsang-ul palkhi-nun]  
 detail-ADN personal.information-ACC disclose-ADN  
 kes-un twu salam motwu pwutamsuleweha-ko.iss-ta"-ko]  
 KES-TOP two person all unwilling-PRG-DEC-COMP  
 cenha-yss-ta.]  
 tell-PST-DEC

'On 24th, Keyeast, the agency of E-Hyun So, said that, while saying "E-Hyun So's boyfriend is now engaged in a business that is not related to the entertainment world", "because (the boyfriend) is a non-celebrity, both are unwilling to disclose the detailed personal information (of the boyfriend)." (D. Jung)

KAIST

42.

[C1 ikes-i palo  
 [C1 this-NOM in.itself  
   [C2 nay-ka  
     [C2 I-NOM  
       wuli nala-ka pantusi kwangpok-toy-nun  
       our country-NOM infalliblyliberate-PASS-ADN  
       [C3 nal-i iss-uli-lako ]  
       [C3 day-NOM exist-FUT-COMP]  
       mit-nun ]  
       believe-ADN ]  
 kkataalk-i-ta ]  
 reason-COP-DECL ]

'This is in itself the reason why I believe there will exist a day when our country infallibly be liberated\*.' (D. Jung)

43.

[C1 kukes-i palo  
 [C1 that-NOM in.itself  
   [C2 Mwuay-ka  
     [C2 Mwuay-NOM  
       choki hankwuk sitan-uy kwusengwen-tul-i cini-n  
       early Korean poetry.scene-GEN member-PL-NOM have-ADN  
       [C3 sengcang paykyeng, mwunhwa hwankyeng-kwa-nun sangtanghi talu-n]  
       [C3 developmental background cultural environment-with-TOP considerably  
       be.different-ADN ]  
       yeken-ul cini-n ]  
       given.condition-ACC have-ADN]  
 cem-i-ta. ]  
 point-COP-DECL]

'That is in itself the point where Mwuay has considerably different given conditions compared with the developmental backgrounds and the cultural environments of the members of early Korean poetry scene.'

44.

[C1 ikes-i palo  
 [C1 this-NOM in.itself  
   [C2 wuli-tul-i ettehkey  
     [C2 we-PL-NOM how  
       [C3 sayngmyeng-i mwues-i-nci-lul ]  
       [C3 life-NOM what-COP-Q-ACC ]  
       cikkwancekulo al-ko.iss-nunci-ey.tayhan ]  
       intuitively know-PRS-Q-for ]  
 selmyeng-i-ta. ]  
 explanation]

'This is the explanation for how we intuitively know what life is.' (D. Jung)

PUD

45.

[C1 Saqib-un

[C1 Saqib-top

[C2 “wuli-nun

[C2 we-top

twayci-lul

phohamha-y]

pig-acc

include-comp

tayangha-n tongmwul-cong-ulo tongmwulwen-ul chaywu-l]

various-adn animal-kind-with

zoo-acc

fill-adn

[C3 swu

iss-tolok

tow-atalla-ko]

[C3 way

exist-comp

help-request-comp

talun

nala-tul-eykey

towum-ul

yochengha-yss-supni-ta”-lako]

different-and

country-pl-dat

help-acc

request-pst-hon-dec-comp ]

malha-yss-ta].

say-pst-dec ]

‘ Saqib said “we requested other countries for help so that we can find a way to have diverse kinds of animals, including pigs, in the zoo.” ’ (D. Jung)

46.

[C1 hoysa-nun

[C1 company-top

sungkayk-eykey

aykseysu

yokum-ul

pwukwaha-l-ci

passenger-dat

access

fee-acc

charge-adn-Q

[C2 yepwu-nun

[C2 whether.or.not<sub>N</sub>-top

[C3 kak

hangkongsa

pulayntu-ka

kyelcengha-l]

[C3 each airline

brand-nom

decide-adn

mwuncey-lako]

matter-(be)-comp

BBC-eykey malha-yss-ta].

BBC-dat say-pst-dec ]

‘ The company said to BBC that it is a matter that each airline(brand) will decide whether passengers should be charged for the access fee. ’ (D. Jung)

47.

[C1 ku-nun ttohan  
 [C1 he-top also  
 [C2 khulleyin-i  
 [C2 Klain-nom  
 [C3 mal-i eps-ko pihyepcocek-i-n]  
 [C3 speech-nom not.exist-and uncooperative-be-adn ]  
 salam-i -mye  
 person-be-and  
 pepceng simli-ey chamsekha-lyemyen  
 court trial-to attend-in.order.to  
 pepwen chengsa kampang-eyse nao-aya.ha-nuntay]  
 courthouse office.building jail.room-from step.out-should-comp  
 nao-lye.ha-ci.anh-nunta-ko]]  
 step.out-be.willing.to-neg-dec-comp  
 malha-yss-ta].  
 say-pst-dec

' He also said that Klain is an uncommunicative and uncooperative person and he is not willing to step out although he should leave the jail room inside the courthouse building in order to attend court trials. ' (D Jung)

48.

[C1 kunye-ka nayseywu-n iyu-nun  
 [C1 she-nom argue.for-pst.adn reason-top  
 [C2 kukes-i mikwuk kunloca-tul-uy ilcali-wa saynghwal swucwun-ey  
 [C2 it-nom U.S. worker-pl-gen job-and living standard-dat  
 [C3 hay-ka ka-ci.anh-tolok]  
 [C3 harm-nom bring-neg-comp(so.that) ]  
 chwungpwunhi pohoha-ycwu-ci.mosha-n-ta-nun]  
 sufficiently protect-do.for-can.not-prs-comp-adn ]  
 kes-i-ta].  
 KES-be-dec

'The reason that she argued for was that it cannot sufficiently protect (the jobs and the standard of living of the U.S. workers) in a way that it does not bring harms to the jobs and the standard of living of the U.S. workers.'(D. Jung)

49.

[C1 ku-nun

[C1 he-top

[C2 "cwungkwuk

cengpwu-nun

[C2 China

government-top

hongkhong-uy

ippep

mapi-ka

cisok-toy-ci.anh-tolok]

Hongkong-gen

legislation paralysis-nom

continue-pas-neg-comp(so.that)

[C3 haki.wihayse

cwungkwuk-uy

kayip-i

philyoha-tako]

[C3 in.order.to

China-gen

intervention-nom be.necessary-comp ]

sayngkakha-n-ta"-lako]

think-prs-dec-comp

malha-yss-ta].

say-pst-dec

'He said "Chinese government thinks that, in order for the paralysis of Hongkong's legislation to not be continued, China's intervention is necessary".(D. Jung)

50.

[C1 ku-nun

[C1 he-top

[C2 sunowumayn<sub>1</sub>-i

[C2 Snowman-nom

cani

hasun

—

kath-un

Johnny Carson

be.same-adn

salam-i palphansatali-ey oll-aka

caki-lul macwupo-ko] anc-nun]

person-nom step

ladder-on

go.up-and self<sub>1</sub>-acc

face-while

sit-adn

[C3 il-i ilena-l

ke-lako]-nun

[C3 event-nom happen-adn

KES-comp-top

sangsang-to ha-ci.mosha-yss-ul ]

imagine-even do-can.not-pst-adn ]

ke-lako] tespwuthy-ess-ta].

KES-(be)-comp add-pst-dec

'He added that Snowman could not have even imagined that there would happen an event that a person like Johnny Carson goes up on a step ladder and sits down there while facing him.'(D. Jung)

51.

[C1 i.kos-un

[C1 this.place-top

[C2 kutul-i

[C2 they-nom

[C3- ku ciyek-uy hocwu wencwumin-tul-i \_\_namkyenoh-un]

that region-gen Australia native-pl-nom leave-pst.adn

cak-un

khanwu hana-lul

hwumchi-n]

be.small-adn

canoe

one-acc

steal-pst.adn

kos-i-ta.

place-prs-dec



'This place is where they stole one of the canoes that the Australian natives of that region had left.' (D. Jung)

52.

[C1\Chayntulle mich Weylle-wa.kath-un myechmyech yeksahakca-tul-un  
 [C1 Chandler and Weller-be.such.as-adn some historian-pl-top  
 [C2 yengkwuk-uy cwungmwucang pwutay-ka  
 [C2 U.K.-gen heavily.armed army-nom  
 [C3 \_\_ tokca sayngcon-i kanungha-n]  
 [C3 independence survival-nom be.possible-adn ]  
 pyenglyek-ulo phihay-lul pat-ass]-umye  
 troop-with damage-acc receive-pst-and  
 i-nun choycho-uy yeksacek-in saken-i-ess-tako]  
 this-top the.first-gen be.historic-adn event-be-pst-comp

cwucangha-yss-ta].

argue-pst-dec

'Some historians such as Chandler and Weller argued that the heavily armed army of the U.K. got damages from a troop that can survive independently, and that this was the first historic event.' [the meaning of this is unclear, no context] (D. Jung)

53.

[C1 ku-nun ttohan  
 [C1 he-top also  
 [C2 "ileha-n mwunse-uy concay-ka  
 [C2 "such document-gen existence-nom  
 [C3 patatuli-l.swu.eps-ul]  
 [C3 tolerate-can.not-adn ]  
 cengto-uy kyelkwa-lul cholayha-l.swu.iss-ta"]-ko  
 degree-gen consequence-acc incur-can-(prs)-dec-comp

cicekha-yss-ta].

point.out-pst-dec

'He also pointed out "the existence of such a document may incur a consequence of a degree that (one) cannot tolerate".' (D. Jung)

## Latin

ITTB

54.

sicut igitur maxim-ae amenti-ae esset idiota  
thus therefore greatest-GEN foolish-GEN be.SBJV fool

[C1 qui

[C1 who

[C2 ea

[C2 that

[C2 quae a philosoph-o propo-nuntur ]

[C2 which by philosopher-ABL propose-PASS ]

falsa esse ]

false be.INF ]

asserere-t propter hoc quod ea capere non pot-est, ]

assert-3SG because that that understand.INF NEG can-3sg ]

"Just as, therefore, it would be the height of folly for a simple person to assert that what a philosopher proposes is false on the ground that he himself cannot understand it" (Aquinas, Contra Gentiles 1.3.5, trans. Vernon J. Bourke)

55.

[C1 quidam uero,

[C1 someone truly

human-os act-us non alicuius ordinatio-ni subesse credent-es nisi human-ae,

human-ACC.PL action-ACC.PL NEG any.DAT order-DAT believing-PL.NOM unless

human-GEN

[C2 homin-es

[C2 man-ACC.PL

[C3 qui ali-os ordin-ant, ]

[C3 who other-ACC.PL command-3PL.PRES ]

deos esse ]

god-ACC.PL be.INF ]

dix-erunt.]

say-PERF.3PL ]

"Still other people, believing that human acts are not subject to any ordering, other than (that of a) human, have said that men who order others are gods." (Aquinas, Contra Gentiles 3.38.3, trans. Vernon J. Bourke)

56.

[C1 illi igitur

[C1 those therefore

[C2 qui in caus-is universal-ibus,

[C2 who in cause-PL.ABL universal-PL.ABL

[C3 quae sunt medi-ae inter deu-m, ]

[C3 who be.3PL intermediary-PL.NOM between God-ACC ]

qui est uniuersal-issima causa,

who be.3SG universal-SUPER cause

et caus-as particular-es,

and cause-PL.ACC particular-PL.ACC,

poss-unt ordin-em prouidenti-ae perfecte cognosc-ere,]

can-3PL order-ACC providence-GEN perfectly know-INF ]

medii sunt ]

between be.3PL ]

"So, those who can perfectly know the order of providence in the universal causes, which are intermediaries between God, Who is the most universal cause, and particular causes are intermediate...." (Aquinas, Contra Gentiles 3.80.9, trans. Vernon J. Bourke).

57.

[C1 necnon et illi  
[C1 also and those  
[C2 qui omnia  
[C2 that all  
[C3 quae providentiae subsunt, ]  
[C3 which to providence be.subject.3PL ]  
ex necessitat-e conting-ere ]  
from necessity-ABL happen.INF ]  
arbitr-aba-ntur, sicut stoic-i. ]  
believe-IPFV-3PL thus Stoic-PL ]

"...also by those who thought that all things (that are) subject to providence occur of necessity, as the Stoics did." (Aquinas, Contra Gentiles 3.96.9, trans. Vernon J. Bourke)

58.

[C1 nam et hoc ipsum  
[C1 Indeed and this itself  
[C2 quod naturalis ordo,  
[C2 that natural order  
[C3 institu-tus secundum ea ]  
[C3 build-PTCP upon those ]  
quae sunt frequenter,  
that be.3PL frequently  
quandoque defici-at, ]  
sometimes fail-3SG ]  
providenti-ae sube-st diuin-ae. ]  
providence-DAT be.subject-3SG divine-DAT ]  
" Indeed, the very fact that the natural order, which is based on things that happen in most cases, does fail at times is subject to divine providence. " (Aquinas, Contra Gentiles 3.99.9, trans. Vernon J. Bourke)

59.

...  
[C1 si haeretic-i  
[C1 if heretic-NOM.PL  
[C2 qui  
[C2 who  
[C3 corp-oris nostr-i de-um esse auctor-em ]  
[C3 body-GEN 3PL.POSS-GEN god-ACC be.INF author-ACC ]  
neg-ant, ]  
deny-3PL ]  
huiusmodi corporalia obsequia de-o exhibita reprehend-unt.]  
likewise bodily worship god-DAT display reprehend-3PL ]

"... if heretics who deny that God is the author of our body condemn such manifestations." [bodily acts of worship to God] (Aquinas, Contra Gentiles 3.119.5, trans. Vernon J. Bourke)

60.

[C1 quidam uero etiam

[C1 someone truly also

[C2 ea

[C2 those

[C3 quae infra homin-em sunt secundum natur-am, ]

[C3 that below man-ACC be.3PL according.to nature-ACC ]

hom-ini tamen colend-a esse ]

man-DAT cultivated-PL even be.INF]

dic-eba-nt... ]

say-IMPERF-3PL]

Indeed, some men said that even things below man's level in nature are to be honored with divine cult...(Aquinas, Contra Gentiles 3.120.4, trans. Vernon J. Bourke)

61.

[C1 pauperes

[C1 poor-PL

[C2 qui ex his

[C2 who from that

[C3 quae ab aliis dantur ]

[C3 which from others give.PASS ]

sustent-ari ]

sustain-PASS ]

deb-ent, necessitat-es su-as al-iis expon-ant ]

must-3PL need-ACC.PL their-ACC.PL other-DAT.PL show-3PL ]

"paupers who are supported by the gifts of others [from what is given by others] have to reveal their needs to others "

(Aquinas, Contra Gentiles 3.132.23, trans. Vernon J. Bourke)

62.

[C1 illi uero

[C1 those truly

[C2 qui posuer-unt

[C2 who claim.PERF-3PL

anim-am,

soul-ACC

[C3 quae est forma humani corporis, ]

[C3 which be.3sg form human body ]

non esse intellect-um per essenti-am,

NEG be.INF intellect-ACC by essence-ACC

sed in ea esse refulgentiam quamdam intellectus

but in it be.INF radiance certain intellect

[C3-B qui est separatus, ]

[C3-B which be.3SG separate ]

et unus communis omn-ibus, ]

and one common all-ABL ]

pon-unt anim-am... ]

claim-3PL soul-ACC ]

"They who have stated that the soul, which is the form of the human body, is not essentially the intellect, but in it is a certain radiance of the intellect, which is separate, and one in common with all, propose that the soul... " <http://www.corpusthomicum.org/snp40491.html>

## Perseus

63.

[C1 quamquam isti

[C1 Although those

[C2 qui

[C2 who

[C3 Catilin-am Massili-am ire ]

[C3 Catiline-ACC Marseilles-ACC go.INF]

dict-it-ant ]

say-freq-3PL]

non tam hoc quer-untur quam ver-entur. ]

NEG so this complain-3PL than fear-3PL ]

"Although those men who keep saying that Catiline is going to Marseilles do not complain of this so much as they fear it; "

Cicero Catiline 2.7. Trans. C. D. Yonge

64.

[C1 victor Sulla

[C1 victor S

[C2 quom Damasippum et alios eius mod-i,

[C2 when D and others that way-GEN

[C3 qui malo rei publicae crever-ant, ]

[C3 who evil thing-PL public-GEN grow-3PL ]

iugul-ari ]

kill-PASS.INF ]

iuss-it]

order.PERF-3sg ]

"When the conqueror Sulla ordered the killing of Damasippus and others of that kind, who had become prominent to the detriment of the state..."

Sallust Catiline 51, trans. J. C. Rolfe

65.

[C1 A. Manlius Torquatus

[C1 A M T

[C2 bell-o Gallic-o fili-um su-om,

[C2 war-ABL Gallic-ABL son-ACC his-ACC

[C3 quod is contra imperium in host-em pugn-ave-rat, ]

[C3 because he against order enemy-ACC fight-PLUPERF-3SG ]

nec-ari ]

kill-PASS.INF ]

iuss-it ]

order.PERF-3sg ]

"Aulus Manlius Torquatus, during the war with the Gauls, ordered the execution of his own son, because he had fought against the enemy contrary to orders, "

Sallust Catiline 52, trans. J. C. Rolfe

## PROEIL

66.

[C1 Iesus autem

[C1 Jesus immediately

[C2 verbo

[C2 word-ABL

[C3 quod dice-batur ]

[C3 which speak-PASS ]

aud-ito ]

hear-PTCP.ABL ]

ait archisynagog-o ]

said synagogue.leader-DAT ]

Mark 5.36, Vulgate

'As soon as Jesus heard the word that was spoken, He said to the ruler of the synagogue...' (NKJV)

67.

si neque popul-i iuss-u neque pleb-is scit-u

if neither people-GEN command-ABL neither commoners-GEN appointment-ABL

[C1 is

[C1 3PL

[C2 qui

[C2 who

[C3 se dedic-asse

[C3 self dedicate-INF

dic-eret ]

say-IMPERF.SBJV.3SG ]

nominatim ei rei praefectus ... ]

by.name 3PL.DAT thing.DAT appoint-PASS ]

Cicero Atticus 4.2.3. /74.3

"If neither by order of the people nor vote of the plebs the party alleging that he had dedicated [lit: he who himself-dedicate(INF) claimed] had been appointed by name to that function..."Translated by Evelyn Shuckburgh (1900)

"... the person claiming to have consecrated it was not commissioned by name thereto by an order of the people or resolution of the plebs" (Bailey 1999: 293)

68.

[C1 Scaurus

[C1 S

qui erat paucis diebus illis absol-utus

who be.3SG.IMPERF few days acquit-PASS

cum ego patr-em eius ornati-ssim-e defend-issem

when I father-ACC his.ACC ornate-SUPER-ADV defend-1SG.PLUPERF.SBJV

[C2 obnuntiation-ibus per Scaevol-am interpos-itis singul-is di-ebus usque ad Kal Octobr

[C2 bad.news-ABL.PL by S-ACC inserted-ABL.PL each-ABL.PL day-ABL.PL until to kalends Oct

[C3 quo ego haec die scripsi ]

[C3 on.which I that day write.1sg.PERF ]

sublat-is ]

removed-ABL]

popul-o tributim dom-i suae satis fec-erat ]

people-DAT by.tribe house-ABL his.ABL enough make-PERF.3SG ]

Cicero Atticus 4.17.

"Scaurus, who had been acquitted a few days before,[4] after a most elaborate speech from me on his behalf—when all the days up to the 29th of September (on which I write this) had one after the other been rendered impossible for the comitia by notices of ill omens put in by Scaevola—paid the people what they expected at his own house, tribe by tribe. " Translated by Evelyn Shuckburgh (1900)

"A few days ago Scaurus was acquitted, part of him being defended by me in my best style. Every day up to 29 September, the day I write this letter, having been voided by Scaevola with reports of bad auspices, he has given the public its due at his own house, tribe by tribe. " (Bailey 1999 vol 2: 13)

69.

[C1 ii

[C1 3PL

[C2 qui

[C2 who

[C3 arm-is pos-itis ]

[C3 weapon-PL.ABL put-PTCP.ABL]

ad imperat-orum fid-em confug-ient

to leader-GEN-PL mercy-ACC appeal.to-FUT.3PL

quamvis murum aries percusserit ]

although wall ram strike.PERF]

recipiendi]

receiving ]

Cicero De Officiis, 1.35.

"those who lay down their arms (lit: arms laid down) and throw themselves upon the mercy of our generals, even though the battering-ram has hammered at their walls, receive...."

70.

[C1 Vera autem et sapiens anim-i magnitudo  
[C1 true also and wisdom soul-GEN greatness  
[C2 honest-um ill-ud  
[C2 honesty-ACC that-ACC  
[C3 quod max-ime natura seq-uitur ]  
[C3 which.ACC most-SUPER nature follow-3sg.PRES ]  
in fact-is po-situm non in glor-ia ]  
in deed-ABL.PL claim-PERF.PASS not in fame-ABL]  
iudic-at ... ]  
judge-3sg.PRES ]

Cicero De Officiis

"Moreover, true and philosophic greatness of spirit regards the moral goodness to which Nature most aspires as consisting in deeds, not in fame..."(trans. Walter Miller, 1913)

71.

[C1 et calo-nes  
[C1 and servant-PL  
[C2 qui ab decuman-a port-a ac summ-o iug-o coll-is  
[C2 who from decuman-ABL gate-ABL to highest-DAT ridge-DAT hill-GEN  
[C3 nostros victor-es flum-en trans-ire ]  
[C3 1PL.ACC victor-ACC.PLriver-ACC cross-INF ]  
conspex-erant ]  
see-3PL.PLUPERF ]  
praedandi causa egress-i  
theft purpose go.out.PTCP-PL  
[C2B cum respex-issent et host-es  
[C2B when look.back-3PL.PLUPERFand enemy-ACC.PL  
[C3B in nostris castris vers-ari  
[C3B in our camp turn-INF  
vid-iss-ent ]  
see-PLUPERF-3PL ]  
praecipites fug-ae sese mand-abant  
hastily flight-DAT self commit-3PL.IMPERF

Caesar's Gallic Wars 2.24

The Works of Julius Caesar, (parallel English/Latin) tr. W.A. McDevitte and W.S. Bohn [1869], at [sacred-texts.com](http://sacred-texts.com)

"...and the camp-followers who from the Decuman Gate, and from the highest ridge of the hill had seen our men pass the river as victors, when, after going out for the purposes of plundering, they looked back and saw the enemy parading in our camp, committed themselves precipitately to flight"

"From the camp gate and hilltop, the camp followers had watched our troops crossing the river in victory, then gone out for plunder; now seeing the enemy prowling in our camp, they fled pell-mell." (O'Donnell 2019)



72.

Caesar's Gallic Wars 2.26

[C1 Caesar

[C1 C.

[C2 cum seventh-ACC legion-ACC

[C2 when septim-am legion-em

[C3 quae iuxta const-iter-at item ]

[C3 which near stand-PLUPERF-3SG to.him ]

urg-eri ab host-e

press-PASS.INF by enemy-ABL

vid-iss-et ]

see-PLUPERF.SJBV-3SG]

tribun-os mil-itum mon-uit....]

tribune-PL.ACC soldier-PL.GEN order-PERF.3SG ]

"Caesar, when he perceived that the seventh legion, which stood close by him, was also hard pressed by the enemy, directed the tribunes of the soldiers..." (McDevitte and Bohn 1869)

"When Caesar saw that the seventh legion nearby was equally under enemy pressure, he ordered the military tribunes ... " (O'Donnell 2019 <https://muse.jhu.edu/book/64416>)

73.

[C1 ..illi

[C1 3PL

[C2 se

[C2 ?

[C3 quae imperar-entur ]

[C3 what.ACC.PL command-PASS ]

facere ]

do.INF ]

di-xer-unt ]

said-past-3PL ]

Caesar's Gallic Wars 2.32

" they said that they would execute his commands." [lit: do what was commanded; facere = infinitive]

74.

Eodem fere temp-ore

Same nearly time-ABL

[C1 Publius Crassus

[C1 P C

[C2 cum in Aquitaniam pervenisset

[C2 when to A-ACC arrive-PERF

[C3 quae

[C3 which

ut ante dictum

as before said

est tertia pars Galli-ae est cum intellexeret ]

is third part Gaul-GEN ]

in iis locis sibi bellum gerendum ]

war-ACC carried-ACC ]

ubi paucis ante annis Lucius Valerius Praeconinus legatus

exercitu pulso

interfectus esset

atque unde Lucius Manlius proconsul

impedimentis amissis

profugisset

non mediocrem sibi diligentiam adhibendam intellegebat

Caesar's Gallic Wars 3.20

"About the same time, P. Crassus, when he had arrived in Aquitania (which, as has been before said, both from its extent of territory and the great number of its people, is to be reckoned a third part of Gaul,) understanding that he was to wage war in these parts, where a few years before, L. Valerius Praeconinus, the lieutenant had been killed, and his army routed, and from which L. Manilius, the proconsul, had fled with the loss of his baggage, he perceived that no ordinary care must be used by him. "(trans. McDevitte & Bohn 1869)

"When Crassus arrived then in Aquitaine, he realized he would have to fight where a few years before the legate Valerius Praeconinus was killed and the army beaten, when the proconsul Manlius had abandoned his baggage and fled.<sup>6</sup> So he knew he needed to move with not a little care." (O'Donnell 2019)

75.

[C1 Caesar

[C1 C

[C2 ea

[C2 that

[C3 quae cogno-verat

[C3 which know-3sg.PLUPERF

dissimul-anda ]

deceive-FUT.PASS.PTCP ]

sibi existim-avit ]

himself decide-PERF.3PL ]

Caesar's Gallic Wars 4.6

"Caesar thought proper to pretend ignorance of the things which he had discovered" (McDevitte and Bohn 1869)

"Caesar decided not to let on what he knew" (O'Donnell 2019 <https://muse.jhu.edu/book/64416>)

76.

[C1 At hostes

[C2 ubi primum nostros equites conspexerunt

quorum erat quinque milium numerus

cum ipsi non amplius octingentos equites haberent

quod ii

[C3 qui frumentandi causa erant trans Mosam profecti ]

nondum redierant

nihil timentibus nostris

quod legati eorum paulo ante a Caesare discesserant atque

is dies indutiis erat ab his petitus

impetu facto ]

celeriter nostros perturbaverunt]

Caesar's Gallic Wars, 4.12

"But the enemy, as soon as they saw our horse, the number of which was 5000, whereas they themselves had not more than 800 horse, because those which had gone over the Meuse for the purpose of foraging had not returned, while our men had no apprehensions, because their ambassadors had gone away from Caesar a little before, and that day had been requested by them as a period of truce, made an onset on our men, and soon threw them into disorder."

The Works of Julius Caesar, (parallel English/Latin) tr. W.A. McDevitte and W.S. Bohn [1869], at [sacred-texts.com](http://sacred-texts.com)

"When first the enemy spotted our cavalry—5,000 of ours, while they had barely 800 horse (because their men crossing the Meuse to forage had not returned)—, our men were unconcerned, because the ambassadors had just left Caesar, requesting a day of truce." (O'Donnell 2019 <https://muse.jhu.edu/book/64416>)

77.

[C1 Caesar

id quod erat suspicatus aliquid novi a barbaris initum consilii

[C2 cohortes

[C3 quae in statione erant ]

se cum in eam partem proficisci ]

ex reliquis duas in stationem succedere

reliquis armari et confestim sese subsequi

lussit ]

Caesar's Gallic Wars, 4.32

"Caesar, suspecting that which was [really the case],--that some new enterprise was undertaken by the barbarians, ordered the two cohorts which were on duty, to march into that quarter with him, and two other cohorts to relieve them on duty; the rest to be armed and follow him immediately."(McDevitte and Bohn 1869)

"Caesar suspected, rightly, some new barbarian plot. He ordered the cohorts on watch to set out with him in that direction, commanded two of the others to stand watch and the rest to arm themselves and follow quickly" (O'Donnell 2019 <https://muse.jhu.edu/book/64416>)

78.

[C1 Caesar  
[C2 etsi idem  
[C3 quod superioribus diebus acciderat ]  
fore videbat ]  
ut si essent hostes pulsi celeritate periculum effugerent  
tamen  
nactus equites circiter triginta  
quos Commius Atrebas  
de quo ante dictum est  
se cum transportaverat  
legiones in acie pro castris constituit ]

Caesar's Gallic Wars, 4.35

"Although Caesar anticipated that the same thing which had happened on former occasions would then occur—that, if the enemy were routed, they would escape from danger by their speed; still, having got about thirty horse, which Commius the Atrebatian, of whom mention has been made, had brought over with him [from Gaul], he drew up the legions in order of battle before the camp. "(McDevitte and Bohn 1869)

" Caesar, though he saw the same thing would happen as did days before—if the enemy were driven back they would escape danger swiftly—still, with about thirty horse that Commius of the Atrebatians—mentioned before—had brought with him, set the legions in order before the camp. "  
(O'Donnell 2019 <https://muse.jhu.edu/book/64416>)

79.

[C1 At Indutiomarus equitatum peditatumque cogere  
[C1 But I. horsemen-ACC soldiers-ACC-and collect.INF  
[C2 eis  
[C2 3PL.ABL  
[C2 qui per aetatem in armis esse non poterant ]  
[C2 who by age in arms be.INF NEG can ]  
in silvam Arduennam abditis ]  
In forest Ardenna hidden-ABL ]  
quae ingenti magnitudine per medios fines Treverorum a flumine Rheno ad initium  
Remorum pertinet  
bellum parare  
instituit ]

Caesar's Gallic Wars, 5.3

"But Indutiomarus began to collect cavalry and infantry, and make preparations for war, having concealed those who by reason of their age could not be under arms, in the forest Arduenna, which is of immense size, [and] extends from the Rhine across the country of the Treviri to the frontiers of the Remi. "(McDevitte and Bohn 1869)

"But Indutiomarus began to gather cavalry and infantry and make ready for war. Those unable to bear arms because of age, he hid in the Ardennes forest—which stretches huge through Treveri country from the Rhine to the boundary with the Remi."(O'Donnell 2019 <https://muse.jhu.edu/book/64416>)

UDante (trans. Paget Toynbee.)

80.

Igitur in hanc Dei manifestissim-am voluntat-em quicunque  
therefore in this God.GEN manifest-ACC will-ACC anyone  
temer-e presumend-o tumesc-unt,  
mad-ABL presumption-ABL grow-3PL.PERF  
si gladius Eius  
if sword his  
qui dicit: «Mea est ultio»  
who say-3sg.PRES mine is vengeance  
de celo non cecid-it,  
from heaven-ABL not fall-PAST.3SG  
ex nunc sever-i iudic-is adventante iudicio pall-ore not-entur.  
From now severe-GEN judge-GEN coming.soon judgement pale-ABL observe-3PL.PASS.SBJV

"Wherefore let all who in mad presumption have risen up against this most manifest will of God,  
now grow pale at the thought of the judgement of the stern Judge, which is nigh at hand, if so be  
the sword of Him who saith, 'Vengeance is mine', be not fallen out of heaven."

<https://dante.princeton.edu/cgi-bin/dante/DispMinorWork.pl?TITLE=Epist&REF=vi.4>

81.

nota infamis Apostolic-am Sed-em usque ad ign-em,  
mark infamy-GEN apostolic-ACC seat-ACC until to fire-ACC  
cui celi  
for.which heaven-PL  
qui nunc sunt  
which now be.PRES.3SG  
et terra sunt reserv-ati,  
and earth be.PRES.SG reserve-PASS  
deturpet  
damage-FUT

...the scar of infamy will disfigure with its mark the Apostolic See even until the fire for which the  
heavens that now are and the earth have been reserved

<https://dante.princeton.edu/cgi-bin/dante/DispMinorWork.pl?TITLE=Epist&REF=xi.15,26>

82.

Ille igitur populus  
that therefore people  
qui  
who  
cunctis athletizantibus  
all-ABL compete.with-ABL  
pro imperio mundi prevaluit,  
for ruling world-GEN prevailed  
de divino iudicio prevaluit.

Thus that people who won the race to rule the world against all competition did so by divine  
decree.

<https://dante.princeton.edu/cgi-bin/dante/DispMinorWork.pl?TITLE=Mon&REF=II%20viii%201-15>

Persian  
83.

دوستانی [که] [تا قبل از این، فریاد] «وای اگر خامنه‌ای حکم جهاد دهد» [شان گوش فلک را کر می‌کرد]، فرصت پیدا کردند [تا ادعای خود را اثبات کنند].

[[[dustān-i [ke [ta qabl az in, faryād-e «vāy agar xamenei hokm-e jahād-am dahad»-eshān gush-e falak rā kar mi-kard]]], forsāt peydā kard-and] [tā ed'eā-ye xod rā esbāt kon-and]].

[C1 [[Friends-CL

[C-1 that.REL

[C-2 until before from this, scream-EZ

[C-3 <<ah if Khamenei order-EZ Jihad-PRON.ACC.1SG give.SUBJ>>-PRON.POSS.3PL ear-EZ sky OBJ deaf PROG-made.3SG]]]

opportunity found did-3PL] [C until claim-EZ self OBJ proof do-SUBJ.3PL]]

“Friends, who until then their cries of “Oh only if Khamenei gives me the order of Jihad” deafened the skies, had the opportunity to prove their claim.” (K. Megerdooonian)

84.

آن چه [هرودوت] [که] [روایت او در این موضوع نباید بی‌مأخذ بوده باشد] [در باب محتوای این مذاکرات نقل می‌کند] [انعکاس واقعیت‌های عصر] [به نظر می‌رسد] و [همین معنی صحت احتمالی آن را تضمین می‌کند].

[[[ān che [herodot [ke [ravāyat-e u dar in mowzu na-bāyad bi-ma'xaz bude bāshad]] dar bāb-e mohtavā-ye in mozāker-āt naql mi-kon-ad]]

en'ekās-e vāqeyat-hā-ye asr be nazar mi-res-ad] va [hamin ma'ni-e sehat-e ehtemālī-e ān rā tazmin mi-kon-ad]].

[C1

[[C-1 that which

[C-2 Herodotus

[C-3 that.COMP [narration-EZ his in this subject NEG-must without-source be-SUBJ.3SG]]

in topic-EZ content-EZ this negotiation-PL tell PROG-do-PRES.3SG]]

echo-EZ truth-PL-EZ age to appearance PROG-arrive-PRES.3SG] and [C this meaning-EZ accuracy-EZ potential-EZ that OBJ guarantee PROG-do-PRES.3SG]]

“What Herodotus, whose narration on this subject should not be unsubstantiated, tells about the content of these negotiations seems to be a reflection of the realities of the age and this guarantees the definition of its potential accuracy.”

(K. Megerdooonian)

CL – Clitic (relative clause clitic)

REL – relativizer

EZ – Ezafe

PRON – Pronoun

ACC – Accusative; POSS – Possessive/Genitive

SG – Singular; PL – Plural

OBJ – Object marker (or Specificity marker)

PROG – Progressive (imperfect) marker

SUBJ – Subjunctive marker

PRES – Present tense (Karine Megardoomian, personal communication)

Turkish

85. Straw, dün Ankara'dan ayrılmadan düzenlediği basın toplantısında, ziyaretinin "verimli ve keyifli" geçtiğini söylerken, hükümetinin Kopenhag'da Türkiye'ye net tarih verilmesini destekleyeceğini yineledi.

[ Straw,

Straw

[ dün Ankara'dan ayrılmadan düzenlediği basın toplantısında ],

yesterday A-from before.leaving organized press meeting

[ [ ziyaretinin "verimli ve keyifli" geçtiğini ]

his visit productive and pleasing passed-NMNL

söylerken ] ,

saying-while

[ [ hükümetinin Kopenhag'da Türkiye'ye net tarih verilmesini ]

his government K-in Turkey-to clear date given

destekleyeceğini ]

support

yineledi. ]

Repeated.

"Straw, in the press meeting that he organized yesterday before leaving Ankara, while he was saying that his visit passed "fruitful and pleasing", (he) repeated that he would support his government to give a clear date to Turkey in Copenhagen. " N. Demir

86. Asiltürk,

A.

(Abdullah Gül Tayyip Erdoğan'ın adaydır) şeklinde bir ifade kullanmadığını,

Abdullah Gül Tayyip Erdoğan'ın-(genitive) Is (his) candidate Such a statement Did not use

ancak (Kamuoyu

But public.opinion

Tayyip Erdoğan'ın Abdullah Gül'ü desteklediğini

Tayyip Erdoğan (nominal) that he supports Abdullah Gul

biliyor)

knows that

dediğini

s/he said

bildirdi.

Informed

"Asiltürk, informed that s/he didn't use such a statement that "Abdullah Gül is the candidate of Tayyip Erdoğan", but that (s/he) said that " the public opinion knows that Tayyip Erdogan supports Abdullah Gul" .”N. Demir

87.

[C1 Diğerleri ,

[C1 others

[C2 Bush yönetiminin

[C2 Bush administration.gen

[C3 her iki taraftaki söylemin de kontrolden çıktığını ]

[C3 every two side.DAT.ADJ statement.GEN too control.ABL get.out.of.FNom.3sg.ACC

düşünebileceğini ]

think.ABIL. FNomFut.3sg.ACC

söyledi .]

say.PAST

|            |       |                    |       |     |              |               |    |             |                         |                            |          |
|------------|-------|--------------------|-------|-----|--------------|---------------|----|-------------|-------------------------|----------------------------|----------|
| Diğerleri, | Bus h | yönetiminin        | her   | iki | taraftaki    | söylemin      | de | kontrolden  | çıktığını               | düşünebileceğini           | söyledi. |
| Others     | Bus h | administration.GEN | every | two | side.DAT.ADJ | statement.GEN | to | control.ABL | get.out.of.FNom.3sg.ACC | think.ABIL.FNomFut.3sg.ACC | say.PST  |

Others said that the Bush administration could think statements from both sides got out of control.

N. Demir

88.

[ Analizciler [  
bu hamlenin  
[ bankalar tarafından daha da sert eylemlerin gerçekleştirilmesine ]  
işaret edebileceğini  
söyledi .]

|             |               |          |            |           |       |               |                                   |                                |          |
|-------------|---------------|----------|------------|-----------|-------|---------------|-----------------------------------|--------------------------------|----------|
| Analizciler | bu hamlenin   | bankalar | tarafından | daha da   | sert  | eylemlerin    | gerçekleştirilmesine              | işaret edebileceğini           | söyledi. |
| analyst.PL  | this move.GEN | bank.PL  | by         | more even | harsh | action.PL.GEN | actualize.CAUS.PASS.NMLZ.POSS.DAT | sign make.ABIL.FNomFut.3sg.ACC | say.PST  |

Analysts said that this move could signal even more harsh actions to be actualized by banks.

N. Demir

89.

Bu tür temel kaynak-lar,  
This kind(.of) basic resource-PL,  
Aztek-ler-de takvim-in  
Aztec-PL-LOC calendar-GEN  
bir ölçüm arac-ı olma-nın öte-si-nde,  
one measurement means-3SG.POSS being-GEN more-3SG.POSS-LOC  
hayat-ın akış-ı-nı düzenle-yen bir davranış-lar manzume-si  
life-GEN flow-3SG.POSS-ACC organize-PTCP one behavior-PL poem-3SG.POSS  
olarak işlev-i-ni yerine getir-diğ-i-ni  
being function-3SG.POSS-ACC in.place.of bring-NFUT.PTCP-3SG.POSS-ACC  
kanıtlıyor.  
prove-IMPF

These kinds of basic resources proves that, the Aztec calendar being more than just a means of measurement, fulfilled its function as a poem(? maybe better: view? code? not sure) of behaviors regulating the flow of life.



[C1 These kinds of basic resources [C2 **the Aztec calendar** being more than just a means of measurement] [C3 [C4 regulating the flow of life] as a poem of behaviors]] [C5 fulfilled **its** function] proves that]  
(M. Zaslansky)

90.

Yerel televizyon-lar,

Local TV-PL,

Rodriguez-in,

Rodriguez-GEN

eş-i-nin kendi-si-ni otel-de çalış-an biri-si-yle  
wife-3SG.POSS-GEN own-3SG.POSS-ACC hotel-LOC work-PTCP one.of-3SG.POSS-with

aldat-tığ-ı gerekçesiyle  
deceive-NFUT.PTCP-3SG.POSS because

Walt Disney World Otel-i-ne gel-dik-ten sonra bir oda-da,

Walt Disney World Hotel-3SG.POSS-DAT come-NFUT.PTCP-ABL after one room-LOC

kendi oğlu-nu ve çağır-dığ-ı bir garson-u rehin

own son.3SG.POSS-ACC and summon-NFUT.PTCP-3SG.POSS one waiter-ACC hostage

al-dığ-ı-nı

take-NFUT.PTCP-3SG.POSS-ACC

bildir-di-ler.

report-PST-3PL

Local TV(s) report that Rodriguez has called (them) and, because his own wife cheated on him with someone working at the hotel, after coming to Walt Disney Hotel World, in a room, taken his own son and a waiter hostage.

(M. Zaslansky)

91.

Hisarcıklıoğlu,

Hisarcıklıoğlu

AB-ye üyelik sürecin-de Türkiye için geliştir-il-en katılım önce-si strateji

EU-DAT membership process Turkey for develop-PASS-PTCP entry before-3SG.POSS strategy

kapsamında yer al-an mali işbirliğ-i-nin boyut-u-nun,

within.the.scope place take-PTCP financial cooperation-3SG.POSS-GEN dimension-3SG.POSS-GEN,

this process-GEN more also difficult pass-FUT.PTCP-3SG.POSS-DAT

bu sürec-in daha da zor geç-eceğ-i-ne işaret

et-tiğ-i-ni

sign-NFUT.PTCP-3SG.POSS-ACC

söyle-di.

say-PST

Hisarcıklıoğlu said that this dimension of financial cooperation taking place within the scope of the pre-ascension strategy developed for Turkey's entry to the EU membership process indicates that this process will get more difficult. (M. Zaslansky)

92.

Genel Müdür Sığın,

General Manager Sığın

yeni Bankalar Yasası-nın,

new Banks Law-GEN

mali sistem-in uluslararası standartlar-a taşınma-sı-nda

financial system-GEN international standards-DAT carrying-3SG.POSS-LOC

önemli bir adım ol-duğ-u-nu

important one step be-NFUT.PTCP-3SG.POSS-ACC

ifade et-ti.

state do-PST

General manager Sığın stated that the new Banks Law is an important step in moving the financial system towards international standards. (M. Zaslansky)

93.

Meclis Genel Kurulun-da gensoru önerge-si-nin ön görüşme-ler-i-nde konuş-an

Parliament General Assembly-LOC censure motion-3SG.POSS-GEN before meeting-PL-3SG.POSS-LOC

speak-PTCP

Aksu,

Aksu,

başta İçişleri Bakanlığı-ı olmak üzere güvenlikten sorumlu bütün birim-ler-in ülke güvenliğinin sağlanma-sı için tedbirleri al-dığ-ı-nı

söyle-di.

especially Interior Ministry-3SG.POSS be-INF [about.to](#) security responsible all unit-PL-GEN country

providing-3SG.POSS for precaution take-NFUT.PTCP-3SG.POSS-ACC say-PST

In the General Assembly of the parliament, Aksu, who spoke before the meetings for the votes of no-confidence, said that all responsible units, especially the Ministry of the Interior, are taking precautions to provide the country security.(M. Zaslansky)

Appendix B: English center-embedding examples  
(All spelling, grammar, and punctuation are [sic])

Eng01.

[C1 The claim

[C2 that these SVO orders,

[C3 which are typical of so many inflectionally impoverished languages and of creoles, ]  
are simple ]

is not readily defensible, therefore.] (Hawkins 2014)

Eng02.

[C1 The chances

[C2 that the persons

[C3 who are now being frozen ]  
will return to life ]

are practically indistinguishable from nil. ](Hansson 2020)

Eng03.

I regularly talk about how much I dislike kids, but

[C1 the things<sub>a</sub>

[C2 people<sub>b</sub>

[C3 who<sub>b</sub> profess utter devotion to their welfare ]

do <sub>a</sub> to them ]

appall me.] "Ihatethisoyoudonegood" (<https://imgur.com/gallery/OmXRxNy>  
<https://archive.ph/iMYPb> )

Eng04. (missing VP)

I only remember the bit in Garfield 2 where

[C1 the animal staff of the castle

[C2 that the spoiled nobleman cat

[C3 that Garfield has been switched with ]

\_\_\_ ]

doesn't know how to make lasagne...]

"Ghost Leviathan"

<https://forums.somethingawful.com/showthread.php?threadid=3910844&userid=0&pagenumber=1709#post513487199>

<https://archive.ph/G4U9u>

Eng05. (Missing VP, pre subject embedding)

[C1 Since the days

[C2 when the native Ohlone people,

[C3 who caught and ate the bounty of oysters and abalone and crab that thrived  
throughout the bay,]

V]

San Francisco has been a good place for seafood.] (Jurafsky 2014: 35)

Eng06.

[C1 The fact

[C2 that there are people  
genuinely angry at

someone pointing out that

The Divine Comedy,

[C3 being a derivative work with a few self-indulgences on the

part of its author,

including self-insertion into the narrative, ]

shares characteristics with derivative works

written in the modern day ]

says more about any given person's cultural perspective and, indeed, hangups than

it does about the work itself.

<https://forums.somethingawful.com/showthread.php?noseen=0&threadid=3728926&perpage=40&pagenumber=194#post511876781>

<https://archive.ph/mAslw>

Eng07.

[C1 A person

[C2 who is confident

that their decision

[C3 not to have kids ]

was the right one ]

is problematic somehow?]

<https://metatalk.metafilter.com/25765/Children-and-Climate-Change#1383165>

<https://archive.ph/69sqP>

Eng08.

[C1 Everything

[C2 the nonnie

[C3 who started this ]

posted ]

is gone.]

Eng09.

More generally,

I think

[C1 any theory of consciousness

[C2 that proposes

that a human being

[C3 who is awake and active ]

is no more or less conscious than one

who is anaesthetised,

or even dead, ]

is a theory ]

that can be safely discarded. ]

<https://www.metafilter.com/190767/Is-consciousness-everywhere>

<https://archive.ph/U4Jau>

Eng10.

[C1 The idea that

[C2 acknowledging that

[C3 you gave away a kidney under major surgery ]

in order to raise awareness

is self-centered white saviorism ]

is wild to me. ]

Eng11.

[C1 A Marine officer

[C2 whose viral videos

[C3 criticizing senior officials

for how they withdrew from Afghanistan ]

created a political uproar ]

will plead guilty to several charges

and seek a discharge

that allows him to keep some military benefits,

one of his lawyers said Tuesday. ]

<https://www.seattletimes.com/nation-world/marine-who-criticized-handling-of-afghanistan-withdrawal-to-plead-guilty/>

<https://archive.ph/MRUSz>

Eng12.

[C1 Suggesting

[C2 that someone

[C3 who needs

the paycheck

[C4 they earned ]

to be delivered to them on time

“didn’t prioritize her bills ]

or save smartly” ]

is wildly out of touch ... ] (Green 2021)

Green, A. (2021, October 19). “my employee wasn’t respectful enough after the company messed up her paycheck” Ask A Manager.

<https://www.askamanager.org/2021/10/my-employee-wasnt-respectful-enough-after-the-company-messed-up-her-paycheck.html>

<https://archive.ph/7jXkZ>

Eng13.

[C1 the idea

[C2 that only the people

[C3 who heard the tale straight from Homer’s lips

had the authentic experience of the epics ]

is facially absurd.]

<https://forums.somethingawful.com/showthread.php?threadid=3884594&userid=0&perpage=40&pagenumber=5#post493476903>

<https://archive.ph/g66cG>

Eng14.

[C1 The sense

[C2 that discovering a way

[C3 to somehow breach this barrier ]

would liberate him ]

was compelling. ] (Egan 1994: 12)

Eng15.

There is some rhetorical conflict in the way the essay starts off for putting it in personal terms that seem to echo the kinds of things being argued against, like reaction videos, but the body of the argument isn't anti-personal response, it's saying

[C1 the way

[C2 the kinds of videos

[C3 being described ]

decontextualize or over-explain art ]

are in fact eroding the ability of a potential audience to respond to the art in a fuller sense ]

by those works being hijacked by "explainers" offering blandly reductive thoughts about plot points or subject matter and appropriators who force the works into narrow "lore" contexts for which they were never intended.

<https://www.metafilter.com/193235/unapologetic-gay-filth#8169402>

<https://archive.ph/dGn6f>

Eng16.

[C1 Saying

[C2 men

[C3 who haven't had enough sex ]

are inherently defective ]

in no way reinforces toxic masculinity and objectifies women.]

<https://forums.somethingawful.com/showthread.php?threadid=3982535&userid=0&perpage=40&pagenumber=137>

<https://archive.ph/Dscje>

Eng17.

I know

[C1 what

[C2 the dude

[C3 his name was based on]

did ]

was bad]

Eng18.

[C1 Genuinely indigenous critiques,

[C2 coming out of traditions

with which people

[C3 raised in Western environments ]

are unfamiliar,]

can seem much more strange and difficult.] (Bell 2021)

<https://archive.ph/oft0O>

Eng19.

[C1 and to say that

[C2 someone

[C3 who lionized Hart Crane, Walt Whitman, Elizabeth Bishop and Tony Kushner ]

was ignoring LGBT voices ]

seems at best perilously naïve.]

<https://archive.ph/a24FP>

Eng20.

[C1 The common “vitruvian figure,”

[C2 of which Leonardo’s drawing of a man with arms outstretched

[C3 \_ inscribed within a circle and square

is perhaps the most familiar example \_ ]

is thus an emblem not only of human dignity but of the secret of all beauty and goodness.] (Rose 1972: 17)

Eng21.

[C1 The idea that

[C2 there is a group of people

that are Black,

and a group of people that are White,

and the people

[C3 who are White ]

are inherently superior to the people

who are Black, ]

came about as part of the culture of accepting and justifying mass slavery. ]

Eng22.

[C1 The philosophers

[C2 who favored the idea

that bodies

[C3 falling in empty space ]

did so with a constant and relatively gentle velocity]

were not the crazy dreamers ]

that almost everyone assumed. (Stableford 2006)

Eng23.

While it’s always interesting

to realise that

[C1 something

[C2 which every child

[C3 you’ve met ]

has taken for granted ]

is seen as strange in other parts of the world, ]

what really got us was some of the comments.

<https://www.metafilter.com/193594/Are-you-a-good-person#8181525>

<https://archive.ph/wip/x4DY2>

Eng24.

[C1 Though the take

[C2 that people

[C3 who write bad worldbuilding ]

are inherently bad people ]

is probably the most laughable thing I’ve read in some time.]

<https://forums.somethingawful.com/showthread.php?threadid=3900237&userid=0&perpage=40&pagenumber=390#post519923897> <https://archive.ph/z9X0q>

Eng25.

[C1 The fact  
[C2 that everything  
[C3 I did ]  
was exactly what  
I had planned  
to do ]  
gave me no comfort. ] (Egan 1995)

Eng26.

[C1 (and the idea  
[C2 that the storm  
[C3 that battered Frodo and Sam on the Emyrn Muil ]  
should later that night pass over Helm's Deep during the siege ]  
had to be abandoned). ] (Rees 2011)

Eng27.

[C1 that  
[C2 she wouldn't bother  
to check  
that some of the minorities  
[ C3 she dismisses here was [sic] "young" with "interesting hair," ]  
were very qualified journalists w long histories ]  
reflects all the bigoted assumptions  
that old credentialed media types make about minorities in their field.]

— kang 🐼 (@jaycaspiankang) January 14, 2019

(Original tweet deleted, taken from:

<https://splinternews.com/jill-abramsons-new-book-sounds-like-an-absolute-mess-1831745987>

<https://archive.ph/W6wfG> )

Eng28.

[C1 The possibility  
[C2 that everyone  
[C3 who'd come here before them ]  
had failed to identify a single new exploit ]  
was too grim to consider. ] (Egan 2018)

Eng29.

[C1 But to claim  
[C2 that only the "members of [the] group" of scholars  
[C3 represented in the 1983 collection of essays ]  
have "accepted the Two Versions theory,"  
and that this "group" has been holding the debate hostage for decades now, ]  
is nothing more than a conspiracy fantasy.] (Syne 2016)  
<https://archive.ph/rW9lv>

Eng30.

[C1 The idea  
[C2 that insights  
[C3 like "Aha, I'm still trying  
to prove myself to my mother,  
which is why  
I'm doing such and such self-destructive thing now" ]  
are lying buried,



waiting to be uncovered and processed, ]  
is not even wrong. ] (Rao 2021)  
<https://archive.ph/pk3YL>

Eng31.

Y'all are acting like you've never seen  
[C1 a 43 year old Governor  
[C2 who only won by 30k votes in a State with 21m people  
who he failed  
[C3 to protect from a deadly virus ]  
for 2 years  
so he could suck-up to MAGA base &  
imitate a septuagenarian grifter  
go missing for 2 weeks at Xmas before.]  
NoelCaslerComedy @caslernoel Dec 30, 2021

Eng32.

[C1 The emotional torture  
[C2 she has already put her partner through \_\_\_ with this  
[C3 'we're trying to conceive' ]  
game  
that she's playing ]  
is insurmountable. ]  
[https://old.reddit.com/r/AmltheAsshole/comments/s00x6i/aita\\_for\\_keeping\\_a\\_big\\_secret\\_from\\_my\\_sil/hrz9bv3/](https://old.reddit.com/r/AmltheAsshole/comments/s00x6i/aita_for_keeping_a_big_secret_from_my_sil/hrz9bv3/)  
<https://archive.ph/800fi>

Eng33.

[C1 that guy and everyone  
[C2 who thinks  
what  
[C3 he does ]  
is funny ]  
needs to be beaten over the head with one of his own presents.]  
<https://forums.somethingawful.com/showthread.php?threadid=3982535&userid=0&perpage=40&pagenumber=361>  
<https://archive.ph/1x7TI>

Eng34.

[C1 The fact that  
[C2 anyone considers SpaceX as anything other than a continuation of the transfer of public  
sector science,  
[C3 that was run for the public good, ]  
into the hands of billionaires ]  
is a testament to our propaganda. ]  
Existential Comics, Twitter  
<https://64.media.tumblr.com/98fa3053772a5f126d1f96854921270e/46ea0a901b0ff926-5e/s500x750/d1cb59c1ae52a33d2a8d0efa4a0ab624a291b532.jpg>

Eng35.

[C1 the idea  
[C2 that things  
[C3 that make you feel uncomfortable ]  
are automatically more radical or reflective of a shared community understanding or whatever ]  
is just as much of a dismissive overgeneralization.]  
<https://fail-fandomanon.dreamwidth.org/528401.html?thread=3201941265#cmt3201941265>

<https://archive.ph/RRrI7>

Eng36.

[C1 Driver

[C2 who stopped  
to help  
when truck

[C3 carrying 100 lab monkeys ]  
crashed in Pennsylvania  
and put her hand in one of the cages ]

says

she now has a cough and pinkeye  
after one of the macaques HISSED in her face. ]

[https://i.imgur.com/OzIYbdZ\\_d.webp?maxwidth=760&fidelity=grand](https://i.imgur.com/OzIYbdZ_d.webp?maxwidth=760&fidelity=grand)

Eng37.

[C1 this idea,

[C2 that all

[C3 that is needed  
to make conservatives  
see the light of progress ]

is simply to lift the scales from their eyes ]

is alive and well in liberalism. ] (McNeil 2022)

<https://archive.ph/7N5XS>

Eng38.

[C1 (Number four, using the language of social justice and progressivism

[C2 to argue

that the market

[C3 in which you are selling products ]  
should be less competitive ]

is, well, gross.) ]

<https://www.metafilter.com/194250/30-games-a-day#8204569>

<https://archive.ph/5RfJ7>

Eng39.

I think

[C1 people

[C2 who have the

[C3 "nothing is ever too much" ]  
attitude ]

aren't always as compassionate with other people as  
they might be. ]

<https://fail-fandomanon.dreamwidth.org/533792.html?thread=3236558368#cmt3236558368>

<https://archive.ph/RHcso>

Eng40.

[C1 Whether or not

[C2 you consider  
the practice

[C3 of using live animals for ballistics research ]  
to be ethical ]

is totally irrelevant. ]

[https://en.wikipedia.org/wiki/Talk:Hydrostatic\\_shock](https://en.wikipedia.org/wiki/Talk:Hydrostatic_shock)

<https://archive.ph/BIMKx>

Eng41.

Are you suggesting that

[C1 thinking

[C2 a movie

that sets out

[C3 to shock and disgust ]

is shocking and disgusting ]

is equivalent to being a bigot? ]

[https://en.wikipedia.org/wiki/Talk:Main\\_Page/Archive\\_163#I.27m\\_sick](https://en.wikipedia.org/wiki/Talk:Main_Page/Archive_163#I.27m_sick)

[https://archive.ph/RFqZi#I'm\\_sick](https://archive.ph/RFqZi#I'm_sick)

Eng42.

[C1 My suggestion that

[C2 a patrol

[C3 equipped with jewelled crosses ]

should enter the forest ]

and attempt to save the priest and Charles Marchand

met with little success. ] (Ballard 2010)

Eng43.

[C1 As time increases, the likelihood

[C2 that an AI with the goal

[C3 of creating music ]

will produce something involving █████-3955 ]

asymptotically approaches one. ]

<https://scp-wiki.wikidot.com/scp-3955>

<https://archive.ph/D7CZU>

Eng44.

[C1 The idea

[C2 that a person

[C3 who has presumably been playing Pokémon Go a fair bit,

and was playing it directly before bed, ]

had an episode

and saw a Pokémon ]

is by no means weird. ]

<https://www.vertigo22.com/2021/07/mystery-pokemon-incubus.html>

<https://archive.ph/Z0I4Q>

Eng45.

[C1 The fact that

[C2 the tilt on her experience

[C3 that she's provided ]

is poised perfectly to plug into reactionary "cancel culture" screeds ]

makes me wary of her trustworthiness in a way that I wouldn't be if she had stuck to her specific experience. ]

<https://www.metafilter.com/194769/Lauren-Hough-on-writing-mentorship-and-losing-her-Lambda-nomination>

<https://archive.ph/PhnTy>

Eng46.

Anyway, there is just no way that

[C1 the claim that

[C2 “maybe the reason

[C3 people are going to the dunes ]

is that

they can’t go

where heterosexuals can congregate” ]

makes sense. ]

<https://retractionwatch.com/2021/11/19/sand-sun-sea-and-sex-with-strangers-paper-did-not-need-human-subjects-research-protection-approval-says-author/#comment-2029785>

<https://archive.ph/EGwvT>

Eng47.

[C1 In light of this, any claim

[C2 wedded couples

[C3 trying to entice the stork down their chimney ]

were granted fornication permits ]

crashes against the rock of the wrong word being used. ]

<https://www.snopes.com/fact-check/what-the-fuck/>

<https://archive.ph/L0Ev3>

Eng48.

but to my cousin, i’m pretty sure

[C1 that the idea

that his problems were because of jokes

[C2 and that the way

[C3 to respond to jokes ]

is with violence ]

would have been pathetic and insulting. ]

<https://forums.somethingawful.com/showthread.php?threadid=3798595&userid=0&perpage=40&pagenumber=1025#post522543172> <https://archive.ph/oSl4L>

Eng49.

[C1 The reveal at the end

[C2 that a wise character

[C3 who teaches the lead about Candyman ]

was somehow doing Candyman’s bidding ]

or otherwise preparing the way for Candyman

neither makes much sense to me nor adds anything to the story.] (DeBoer 2022a)

<https://archive.ph/KMfjk>

Eng50.

[C1 The critique

[C2 that men

[C3 who watch porn

view their partners as a live sex doll ]

has been around since the 70s.]

<https://freddiedeboer.substack.com/p/the-deprivation-model-hurts-us-all/comment/5897214?s=r>

<https://archive.ph/pjyWK>

Eng51.

[C1 Yeah, the fact

[C2 that they think  
that someone

[C3 who is *literally unconscious* ]  
isn't vulnerable

is scary.]

[https://old.reddit.com/r/SubredditDrama/comments/u1noi6/op\\_asks\\_rlegaladvice\\_how\\_to\\_avoid\\_a\\_nonconsensual/](https://old.reddit.com/r/SubredditDrama/comments/u1noi6/op_asks_rlegaladvice_how_to_avoid_a_nonconsensual/)

<https://archive.ph/1LyyM>

Eng52.

[C1 The fact

[C2 that most of the authors

[C3 mentioned ]

happen to be male ]

is kinda more of a consequence of what

the industry generally puts its PR money and time behind. ]

[https://old.reddit.com/r/HobbyDrama/comments/u0jd14/hobby\\_scuffles\\_week\\_of\\_april\\_11\\_2022/i4o3hp1/](https://old.reddit.com/r/HobbyDrama/comments/u0jd14/hobby_scuffles_week_of_april_11_2022/i4o3hp1/)

<https://archive.ph/UT8IU>

Eng53.

[C1 To say

[C2 that parents in Los Angeles, Las Vegas and Honolulu

[C3 who were looking for Franklin and Dora ]

were unhappy

when they instead got stand-up comediennes

talking about how painful their vaginas were after childbirth

and episodes of The Brady Bunch with Carol

snarking up the reruns Pop Up Video-style ]

is a serious understatement ]

<https://tvtropes.org/pmwiki/pmwiki.php/NetworkDecay/MajorShiftsThatFit>

<https://archive.ph/Ozzyh>

Eng54.

[C1 The reasoning

[C2 the outgoing Magic World President

[C3 (who is later depicted as a secret Grindelwald supporter) ]

gives ]

is that Magic Hitler can be defeated in the Marketplace of Ideas...]

<https://forums.somethingawful.com/showthread.php?noseen=0&threadid=3919233&perpage=40&pagenumber=189#post522989480>

<https://archive.ph/jb4Gd>

Eng55.

[C1 To suggest

[C2 that the worst part

[C3 of vacationing in a van ]

is sleeping in a van ]

is not fair to the other aspects of the endeavor, ]

<https://www.metafilter.com/195102/I-Lived-the-VanLife-It-Wasnt-Pretty>

<https://archive.ph/VD4if>

Eng56.

[C1 The

[C2 'everyone

[C3 who buys a game ]

deserves to enjoy it' ]

point is especially something I take issue with ]

[https://old.reddit.com/r/HobbyDrama/comments/u5osir/hobby\\_scuffles\\_week\\_of\\_april\\_18\\_2022/i5je9q9/](https://old.reddit.com/r/HobbyDrama/comments/u5osir/hobby_scuffles_week_of_april_18_2022/i5je9q9/)

<https://archive.ph/l1kDW>

Eng57.

[C1 but whatever

[C2 the AI

[C3 that kills us ]

really does ]

will probably be weirder than that. ] (Alexander 2022)

<https://archive.ph/wip/NJY4G>

Eng58.

Anyway, I just think

[C1 the reinvention of basic questions

[C2 that you can't answer

because anything

[C3 you could possibly say ]

would prove

that you're a heretic ]

is kind of interesting. ]

<https://archive.ph/FxMg9>

Eng59.

[C1 to notice

[C2 that some of the things

[C3 people complain about ]

exist ]

is not to agree with any of the conclusions

they draw from that, or with stances they hold ]

<https://archive.ph/faxFh>

Eng60.

i suppose

the fact

that old guard Republicans

who were just evil corporate puppets

losing ground to the people

who bought into their bullshit over the years

[vvv]

is evidence that

they might just do it

because they're red eyes maniacs.

<https://forums.somethingawful.com/showthread.php?threadid=3798595&userid=0&perpage=40&pagenumber=1040>

Alternative parse:

i suppose

the fact

that old guard Republicans

who were just evil corporate puppets

[are] losing ground to the people

who bought into their bullshit over the years

is evidence that

they might just do it

because they're red eyes maniacs.

[original text deleted and not saved]

Eng61.

[C1 The idea, however,

[C2 that tuberculosis – a disease

[C3 characterised by wasting, diarrhoea, coughing and the spitting of blood – ]

could enhance its victim's beauty ]

is less relatable. ] (Day 2018)

Eng62.

[C1 The People

[C2 Hurt By The

[C3 "It's a Beautiful Journey" ]

School of Mental Health ]

Are the People with Mental Disorders.] (DeBoer 2022)

Eng63.

[C1 The Silent Generation

[C2 (who Studs,

[C3 mentioned upthread, ]

named the Greatest) ]

fought fascism, true]

<https://www.metafilter.com/195318/The-Worlds-a-Mess#8247691> <https://archive.ph/3bLpn>

Eng64.

[C1 pointing out that

[C2 the guy

[C3 who literally got face surgery

and absolutely destroyed his body with steroids/hormones ]

probably has body issues ]

isn't a racial thing ]

<https://forums.somethingawful.com/showthread.php?threadid=3918745&userid=0&perpage=40&pagenumber=1664#post523515517> <https://archive.ph/vW4QQ>

Eng65.

[C1 This claim,

[C2 which Misali's efforts

[C3 to explore the song's true history ]

suggest

is categorically false, ]

came courtesy of one Giovanni Sconfienza.] (Winslow 2021)

Eng66.

[C1 And the obvious impulse

[C2 to say

that someone

[C3 who faces total debilitation from their disorder ]

should, in fact, be a higher priority for the medical and therapeutic communities ]

is treated as the height of bigotry. ] (DeBoer 2022b)

Eng67.

I think

[C1 assuming

[C2 someone

[C3 saying, 'please tolerate me', ]

means 'everyone should do this', ]

is an easy jump

to make

when the person is saying something to the effect of,

'please tolerate me being more moral than you'. ]

<https://astralcodexten.substack.com/p/in-partial-grudging-defense-of-the/comment/6783443?s=r>

<https://archive.ph/y43ST>

Eng68.

[C1 Nothing

[C2 those

[C3 trapped in this world ]

do ]

will ever relieve their torment. ]

<https://tvtropes.org/pmwiki/pmwiki.php/AndIMustScream/Literature> <https://archive.ph/qq2IZ>



Eng69.

[C1 Saying that

[C2 anyone

[C3 who didn't obtain identical results to you ]

obviously just didn't work hard enough

(or has a disability) ]

is also an insult. ]

<https://forums.somethingawful.com/showthread.php?threadid=3198184&userid=0&perpage=40&pagenumber=1016>

Eng70.

[C1 The chance of

[C2 anyone

[C3 involved in this production ]

being able

to orchestrate an aerial puppet explosion without

losing an arm ]

seems slim. ] (Hill and Hill 2017)

Eng71.

[C1 I really hate the

[C2 "no one

[C3 who works a full time job ]

should live in poverty"]

discourse...]

<https://imgur.com/gallery/5aqfCY1>



Olayemi Olurin

@msolurin

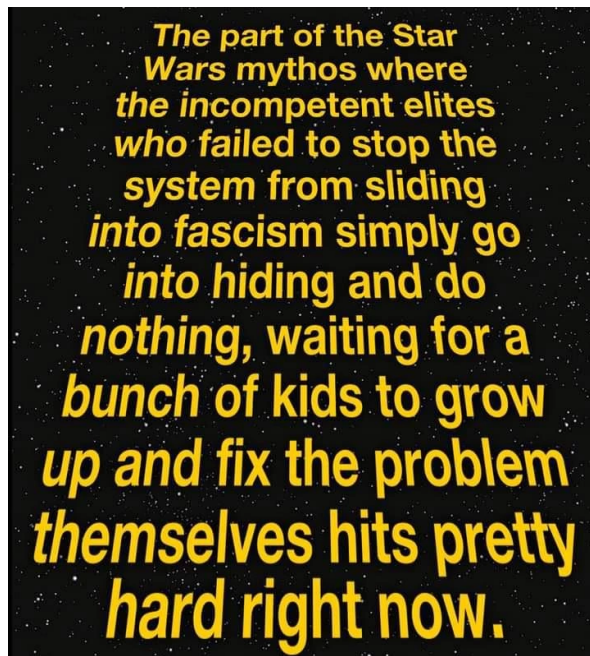
I really hate the "no person who works a full time job should live in poverty" discourse because it should simply be that nobody deserves to live in poverty. We gotta let go of this idea that we work in exchange for worth. People are innately worthy + deserving of the basics

7:03 PM · 06 Mar 21 · [Twitter for iPhone](#)

**38K** Retweets **756** Quote Tweets **163K** Likes

Eng72.

[C1 The part of the Star Wars mythos  
[C2 where the incompetent elites  
[C3 who failed  
to stop the system from  
sliding into fascism ]  
simply go into hiding  
and do nothing,  
waiting for a bunch of kids  
to grow up  
and fix the problem themselves ]  
hits pretty hard right now. ]



Eng73.

[C1 But those  
[C2 to whom the idea  
[C3 of playing mathematical games with literature ]  
appeals ]  
should enjoy this volume greatly. ] (Yee 1996)

Eng74.

[C1 Arguments that  
[C2 those  
[C3 who suffer from a given disability ]  
are in any way superior to others ]  
amount to an attempt to leverage society's sympathy for disability to gain favor in the social hierarchy.]  
(DeBoer 2022d)

Eng75.

[C1 Over the course of a single stand-up comedy bit, something  
that had been in the fuzzy background of pop culture for years, if not decades  
—how  
[C2 Bill Cosby's predilection  
[C3 for harshly judging others  
for swearing or not wearing a belt ]  
clashed with the many, many accusations  
that he had been drugging and molesting much younger women for a half century— ]  
was thrust into the forefront. ] (Nathan Rabin <https://www.patreon.com/posts/skepticism-and-67829724> )

Eng76.

[C1 However, his belief  
[C2 that everyone  
[C3 who tried ]  
could be a parasite ]  
and his refusal  
to see  
that happiness leads to materialism,  
brought about his fall. ](Manguel & Guadalupi, G. 2000: 144)

Eng77.

[C1 The fact that  
[C2 anything  
[C3 resembling a manuscript ]  
was finally assembled ]  
is nothing short of miraculous.] (Kelly 2005: 323)

Eng78.

[C1 However, the fact that  
[C2 the remains of animals  
[C3 that are not conodonts ]  
have also been found inside *Typhloesus* ]  
speaks against the idea that  
the conodonts were its young and  
is more in favour of  
them having been prey. ] (Sigvin 2020)

Eng79.

[C1 The tamed-fox  
she called "Baby,"  
[C2 who  
[C3 when she found us ]  
followed her like a child  
and was doted on like so, ]  
was more than proof enough that she understood the same principles.] (Bajda 2022)

Eng80.

[C1 The fact

[C2 that the effects

[C3 observed here ]

occurred even in the absence of adjacency of either the embedded verb with the critical verb or the semantic

distractor with the critical verb ]

challenges accounts associated with local coherence.] (Van Dyke 2007)

Eng81.

[C1 the fact

[C2 that the guy

[C3 who fired indiscriminately in the crowd

*immediately went and extensively discussed his attempted murder in CSPAM via a sockpuppet* ] is a problem.]

<https://forums.somethingawful.com/showthread.php?threadid=3977737&userid=0&perpage=40&pagenumber=99#post518112480>

<https://archive.ph/LAZ1d>

Eng82.

[C1 The theory

[C2 that unobservables

[C3 posited by scientific theories ]

exist ]

is referred to as scientific realism. ]

<https://en.wikipedia.org/wiki/Unobservable> <https://archive.ph/6see5>

Eng83.

[C1 The fact that

[C2 who gets

[C3 to be "white" ]

changes depending on who

those in power currently dislike

(variously excluding Irish, Italians, Slavs, and many others) ]

should tell you all

you need to know about what a problematic idea. ]

[https://old.reddit.com/r/badlinguistics/comments/vv9tma/ahh\\_yes\\_my\\_favourite\\_language\\_family\\_the\\_poc/iflndrg/](https://old.reddit.com/r/badlinguistics/comments/vv9tma/ahh_yes_my_favourite_language_family_the_poc/iflndrg/)

<https://archive.ph/QcQVY>

Eng84.

[missing a subject?]

[C1 The idea that

[C2 [NNN]

[C3 state formation is not a violent process (a fairly well established thing in the literature)

]

is somehow pro-genocide ]

is, I don't know, silly? Laughable? Facile?]

<https://www.metafilter.com/195994/The-brakes-are-wearing-thin#8273742> <https://archive.ph/obtqS>  
Eng85.

[C1 otherwise my little cretonne summer dress  
[C2 that my little dressmaker  
[C3 who makes things specially cheaply for me ]  
made for me ]  
would have had it. ](Queneau 2018)

Eng86,

[C1 The fact  
[C2 his own brother is asking him in a panic over the phone if  
what  
[C3 he's being charged for ]  
is true ]

makes Glenn understand that his connections are not going to save him.]

<https://tvtropes.org/pmwiki/pmwiki.php/Film/TheBookOfHenry> <https://archive.ph/C5sEW>

Eng87.

[C1 That  
[C2 no one  
[C3 who's supposed to ]  
is watching the sky ]

is one of many tropes

CinemaSins points out. ]

<https://tvtropes.org/pmwiki/pmwiki.php/Main/ObliviousAstronomers> <https://archive.ph/QWMSj>

Eng88.

[C1 Finding out that  
[C2 what  
[C3 you've got ]  
can be treated ]  
is a big help. ](Spoken conversation)

Eng89.

[C1 The fact that  
[C2 the story of serotonin and depression  
[C3 that was promulgated in the 1990s ]  
is likely false  
does not at all imply  
that there is no chemical/neurological/physiological element to depression! ](DeBoer 2022e)

Eng90.

[C1 The fact that  
[C2 stacked sentences  
[C3 that would ordinarily cause perceptual difficulty ]  
can be simplified through word order variation  
suggests the possibility  
that flexible word order might itself be a device  
invented by languages  
that are plagued by such structures. ] (Hakuta 1981: 235)

Eng91.

[C1 The idea

[C2 that anyone

[C3 who examines and reports on what  
terrible people are doing ]

is morally suspect by association ]

is a very dangerous mindset and social norm to cultivate ]

<https://fail-fandomanon.dreamwidth.org/557416.html?thread=3393127528#cmt3393127528>

Eng92.

[C1 The way

[C2 that some of the meat-eating students

[C3 who read it ]

react to it ]

is incredibly weird. ]

<https://fail-fandomanon.dreamwidth.org/557653.html?thread=3393992021#cmt3393992021>

<https://archive.ph/fFV4B#cmt3393992021>

Eng93.

[C1 The way

[C2 the champions of the modern synthesis –

[C3 who by this point dominated university biology departments – ]

dealt with potentially destabilising new findings ]

was by acknowledging

that such processes happen sometimes...](Buranyi 2022)

Eng94.

[C1 ...the door

a writer could step through

to make a career 50 or even 20 years ago,

the one

[C2 opening onto a life where

someone

[C3 who works hard and does well ]

could buy a house on the strength of that work alone, ]

has been slammed shut.]

<https://www.metafilter.com/196189/The-Money-is-in-All-the-Wrong-Places> <https://archive.ph/iNU6G>

Eng95.

[C1 the moral intuition

[C2 that money

[C3 spent helping the global poor ]

goes farther than money

spent on the domestic poor ]

seems to be pretty widespread]

<https://freddiedeboer.substack.com/p/effective-altruism-has-a-novelty/comment/8317144>

<https://archive.ph/87eV5>

Eng96.

[C1 The debate

[C2 whether the star

[C3 that was used to calibrate the JWST, ]

deserves its own article or not, ]

was also funny. ]

[https://old.reddit.com/r/HobbyDrama/comments/wpwdre/wikipedia\\_the\\_story\\_of\\_lugnuts\\_or\\_how\\_to\\_create/ikjlwv5/](https://old.reddit.com/r/HobbyDrama/comments/wpwdre/wikipedia_the_story_of_lugnuts_or_how_to_create/ikjlwv5/) <https://archive.ph/MBTyO>

Eng97.

[C1 Authors like Vonnegut and Lem

[C2 not considering what

[C3 they wrote ]

to be pure science-fiction

and not having/not wanting SFWA (science fiction writers of America) membership ]

made certain authors (like Niven and Pournelle) and more than a few wannabe bigName internet people intensely mad.]

<https://forums.somethingawful.com/showthread.php?threadid=3900237&userid=0&perpage=40&pagenumber=544#post525566765> <https://archive.ph/ekxZy>

Eng98.

[C1 The idea

that gods derive their power from

people believing in them and worshipping them

[C2 and that gods

[C3 whom people stop believing in and worshipping ]

will “fade” or possibly even die out ]

pops up fairly frequently in modern popular culture. ]

<https://talesoftimesforgotten.com/2021/12/30/did-ancient-people-really-think-that-gods-people-didnt-believe-in-would-fade/>

<https://archive.ph/G5RqZ>

Eng99.

[C1 The curious belief,

widely spread in former ages—

[C2 that the creatures

[C3 (described in the last chapter)

called “ barnacles ” or “ ship’s barnacles ”

—often found attached in groups to pieces of floating timber in the sea

as well as fixed to the bottoms of wooden ships— ]

are the young of a particular kind of goose

called “ the barnacle goose,”

which is supposed to hatch out of the white shell of the long-stalked barnacle, ]

is a very remarkable example of the persistence of a tradition

which is entirely fanciful. ] (Lankester 1917: 119)

Eng100.

it's really funny to me that

[C1 this half-assed response to Malthus,

[C1 who believed

[C2 that the inability

[C3 to grow more food ]

created

what was basically an inescapable population limit, ]

turned out to be totally correct. ]

<https://argumate.tumblr.com/post/692903945264381952/food-for-man-may-also-be-considered-as-a-com-pound>

<https://archive.ph/7LQQ2>

Eng101.

[C1 Some ppl

[C2 who like

to snigger about

how anyone with an axe to grind

[C3 they cannot neatly assimilate to any familiar ideological categories ]

needs to "log off" ]

have very clearly never talked to anny even mildly eccentric strangers on the train and

would greatly benefit from this experience ]

<https://loving-n0t-heyting.tumblr.com/post/693173161434497024/some-ppl-who-like-to-snigger-about-how-anyone-with>

<https://archive.ph/X5aGr>

Eng102.

Letty from this book isn't quite Anger Is A Gift level of unfortunate implications, but it still has a lot, ranging from how

[C1 the other white lady

[C2 who's introduced

talking about

how the reason

[C3 more women aren't learning at magic college(in the 1840s!) ]

is that they're not motivated enough ]

is inexplicably totally down with

sacrificing herself

to get rid of colonialism and

isn't racist at all ]

to the scene

where the protagonist thinks to himself about

how she 'was not helping the general feminist case

that women were not nervous, pea-brained hysterics'

while she's freaking out because

she just murdered her professor.

<https://fail-fandomanon.dreamwidth.org/560632.html?thread=3413317112#cmt3413317112>



Eng103.

[C1 The fact

[C2 that the dinosaurs

[C3 you hunt in the game ]

are actually aliens ]

that somehow convergently evolved

to look like outdated dinosaur-depictions

is of course ludicrous. ](Sigvin 2020b)

Eng104.

[C1 someone

[C2 who falls for the

[C3 "someone is on their way right now

to buy this

if you don't!" ]

scam, let alone for \$23,000 ]

is probably not very healthy mentally.]

[https://old.reddit.com/r/AmltheAsshole/comments/ci5zhq/aita\\_for\\_using\\_money\\_we\\_earmarked\\_for\\_our\\_6\\_month/ev2366n/](https://old.reddit.com/r/AmltheAsshole/comments/ci5zhq/aita_for_using_money_we_earmarked_for_our_6_month/ev2366n/) <https://archive.ph/aJACo>

Eng 105.

[C1 Seeing

[C2 people

[C3 who appear to be well off (Tesla owners) ]

[C3b who can afford to buy new items ]

shopping at a thrift store ]

might make them feel a bit... uncomfortable. ]

[https://old.reddit.com/r/AmltheAsshole/comments/wzbwum/aita\\_for\\_thrift\\_shopping/im25ofd/](https://old.reddit.com/r/AmltheAsshole/comments/wzbwum/aita_for_thrift_shopping/im25ofd/)  
<https://archive.ph/wuZ3k>

Eng106.

[C1 The noise

[C2 glass

[C3 going into the recycling bin ]

makes ]

is awful ]

and I get to hear this racket several times a day.

<https://fail-fandomanon.dreamwidth.org/561433.html?thread=3419740185#cmt3419740185>  
<https://archive.ph/Rmehc#cmt3419740185>

Eng107.

But the fascist use is not the original use, and

[C1 suggesting

[C2 that anyone

[C3 using that analogy - a **good** analogy in its original context - ]

is a fascist ]

is just wrong.]

<https://argumate.tumblr.com/post/694092335550709760/actual-fascist-mindsets-i-know-that-you-have-had>  
<https://archive.ph/i4SHW>

Eng108.

[C1 the idea that

[C2 psychologically disturbed teenagers

[C3 who shoot up their schools and get jailed for it ]

are somehow representatives of a hegemonic ruling class ]

is insane on its face]

<https://the-grey-tribe.tumblr.com/post/693975282794856448> <https://archive.ph/XCclm>

Eng109.

[C1 the stereotype of

[C2 defense attorneys

[C3 defending “obviously” guilty people ]

all being cynical scumbags ]

is a big pet peeve of mine & imo one of the most insidious forms of cop propaganda.]

<https://bogleech.tumblr.com/post/694225920509296640/theres-people-who-were-seen-as-so-obviously>

<https://archive.ph/pkQL6>

Eng110.

[C1 But then again, assuming that

[C2 a landlord

[C3 renovating a loft ]

will do this correctly ]

is just a LOL.]

<https://forums.somethingawful.com/showthread.php?noseen=0&threadid=3982535&perpage=40&pagenumber=1363#post526004468>

Eng111.

Maybe the comment is meant to indicate that Mr. Wilson can't keep up with Dennis's keen chess mastery, and Dennis is actually going to soon graduate from thrashing his elderly neighbors and move on to the high-stakes world of competitive chess,

[C1 which,

[C2 if the drama

[C3 depicted in the *The Queen's Gambit*,  
now streaming on Netflix, ]

is any guide, ]

would actually be a fairly menacing move on his part.] (Fruhlinger 2022)

Eng112.

[C1 And frankly the idea

[C2 that women

[C3 who don't feel some deep mystical emotional connection to the idea of womanhood, ]  
not to mention those

[C3b who social expectations about how women ought to be  
and dislike the way

they are treated based on their sex, ]

must actually be men deep down ]

is bizarre and extremely sexist.

<https://fail-fandomanon.dreamwidth.org/562204.html?thread=3425099036#cmt3425099036>

Eng113.

[C1 People on meme being like

[C2 "the only reason

[C3 you don't wear makeup ]

is because you think you're better than women who do" ]

does sound fake, though.]

<https://fail-fandomanon.dreamwidth.org/562698.html?thread=3428933130#cmt3428933130>

<https://archive.ph/4jnhv#cmt3428933130>

Eng114.

[C1 Oh yeah, the fact that

[C2 the Wright Brothers' plane is seen as a really, really old event,  
but the last person

[C3 who was alive

when that happened ]

died LAST APRIL ]

is insane ]

<https://fabianocolucci.tumblr.com/post/694900737774403584/for-those-who-dont-know-kane-tanaka-was-a>

<https://archive.ph/IQGUV>

Eng115.

[C1 Intentionally taking an action

[C2 that will likely make  
someone

[C3 who is already having a terrible time through no fault of their own ]

have an even worse time ]

is a bad thing to do ]

[https://old.reddit.com/r/AmltheAsshole/comments/xp4kiz/aita\\_for\\_bullying\\_a\\_disabled\\_kid/iq2a546/](https://old.reddit.com/r/AmltheAsshole/comments/xp4kiz/aita_for_bullying_a_disabled_kid/iq2a546/)

<https://archive.ph/ryEA7>

Eng116.

[C1 Maybe all of those people

[C2 who said

that what

[C3 people really want ]

is clear lucid explanations of important issues by experts with lots of context ]

were just right all along?] (Alexander 2022b)

Eng117.

Remember a lot of the audience has no familiarity with comic books and their conventions,

[C1 the idea

[C2 that a character

[C3 who is killed off ]

will obviously be back within a year maximum by some contrived excuse]

is completely new to them.]

<https://forums.somethingawful.com/showthread.php?threadid=3898382&userid=0&perpage=40&pagenumber=1273#post526533584>

<https://archive.ph/GsDPb>

Eng118.

In fact, for a *lot* of subfields from programming language design all the way up through computability theory and artificial intelligence,

[C1 the fact

[C2 that the mathematical elements

[C3 the computer will be manipulating ]

will eventually be expressed in a binary representation ]

is pretty much irrelevant.] (AdmiralSakai 2018)

Eng119.

[C1 The fact

that these different species look so different from one another,

[C2 and that the only things

[C3 really tying them together]

were mouthlessness and bacterial companions,]

meant that

scientists had to

ask the question:

were these different species really related? ] (Journey to the Microcosmos 2022)

Eng120.

[C1 Nevertheless, the idea

[C2 that a culture, able

[C3 to engineer space-time in ways

we could scarcely comprehend,]

could *fear* us,]

was ludicrous.](Egan 1992: 20).

Eng121.

[C1 The last person

[C2 She

[C3 Who Is Bound To The Sword ]

will ever fall in love with \_ ]

will kill Brynhild... ]

<https://hitmen.thecomicseries.com/comics/149/#content-start>

<https://archive.ph/wLXEA>

Eng122.

[C1 taking over the universe

[C2 without assuring

the existences

[C3 we bring ]

are good existences ]

may not be a good idea.]

[https://old.reddit.com/r/slatestarcodex/comments/y7ygk3/how to take over the universe in three easy steps/isxgh6j/](https://old.reddit.com/r/slatestarcodex/comments/y7ygk3/how_to_take_over_the_universe_in_three_easy_steps/isxgh6j/)

<https://archive.ph/Zxg51>

Eng123.

[C1 Those lapsed, busy,

[C2 usually too tainted by secularism and the exhaustions of everyday life  
to attend with the regularity  
the faith

[C3 they professed ]

would prefer ]

were all here.] (Mieville, C. 2010. *Kraken*.)

<https://language.log.ldc.upenn.edu/nll/?p=29335>

<https://archive.ph/wip/Fodlo>

Eng124.

[C1 Trying

[C2 to explain to someone

that the sheer volume of sodium or soda

[C3 they take in ]

is the reason for being hospitalized again ]

often either gets a lie about what they had or stubbornness about how they did some research and so-and-so said this diet cured their diabetes and don't need to talk to a professional thank you very much. ]

<https://forums.somethingawful.com/showthread.php?noseen=0&threadid=3982535&perpage=40&pagenumber=1550#post527206576>

<https://archive.ph/wip/ywM8w>

Eng125.

[C1 I mean, the arguments that

[C2 all omnipotent beings have free will  
and that beings

[C3 which don't exist ]

don't have free will ]

both seem to be false premises. ]

Eng126.

[C1 The answer to

[C2 'does this being

[C3 which does not exist ]

have free will' ]

is more properly 'mu'.]

[https://old.reddit.com/r/slatestarcodex/comments/yh026l/what do you think about my argument in fav or\\_of/iubfggn/](https://old.reddit.com/r/slatestarcodex/comments/yh026l/what_do_you_think_about_my_argument_in_fav_or_of/iubfggn/)

Eng127.

[C1 Saying

[C2 the way

[C3 someone explains history or writes fiction based on history

is boring ]

is not the same as saying the history itself is boring, inconsequential, etc. ]

<https://fail-fandomanon.dreamwidth.org/571191.html?thread=3486088503#cmt3486088503>

Eng 128.

[C1 To say

[C2 that norms in the society

[C3 that uses a given language ]

about how

to use and

not use that language in various sorts of contexts/settings

are not in some sense part of the language ]

seems debatable. ]

<https://languagehat.com/over-reliance-on-english-hinders-cognitive-science/#comment-4490169>

Eng129.

[C1 the stomach-churning portrayal of

[C2 being a depressed and lonely assistant professor

whose students keep complaining

that the things

[C3 you're making them do ]

aren't "relatable" enough ]

was a little TOO well-done. ]

<https://fail-fandomanon.dreamwidth.org/571848.html?thread=3488374984#cmt3488374984>

Eng130.

[C1 In fact, the elusive dark matter

[C2 that every theoretical physicist

[C3 who's worth his salt

is now searching for ]

may just be information.]

<https://www.zmescience.com/science/news-science/information-fifth-state-matter-0252/>

Eng131.

[C1 The fact that

[C2 multiple fossils of these mouth parts

[C3 representing several individuals ]

have been recovered for the worm species ]

shows it's not a fluke. ] (Thomas 2022).

Eng132.

[C1 Why

[C2 a somewhat dry history of a fantasy land, a set of books

[C3 that certainly lack classic literary merit, ]

are a beloved brand and household name ]

is a bit of a mystery. ] (Dave 2022)

Eng133.

[C1 the picketers

[C2 that decide

to make the lives of random people

[C3 trying to drive around school ]

miserable ]

have some sort of God complex. ]

[https://old.reddit.com/r/UCSD/comments/yx6ga7/do not hit students on strike with your car/iwo84vn/](https://old.reddit.com/r/UCSD/comments/yx6ga7/do_not_hit_students_on_strike_with_your_car/iwo84vn/)

Eng134.

[C1 The first thing

[C2 bacteria

[C3 resting on our food]

do when surrounded by salt descended from above ]

is open nozzles in their body walls and sluice in plenty of water to try to dilute the stinging salt. ]

(Bodanis 1986: 157)

Eng135.

[C1 The way

[C2 that people

[C3 raising this alarm ]

immediately refuse to consider increasing immigration ]

is always their tell. ]

<https://www.metafilter.com/197211/You-say-Eugenics-like-its-a-bad-thing-it-is#8323440>

Eng136.

Assuming

they must have been disabled

even though they demonstrated

they had the ability

to get themselves to the store

to yell at someone

is projection,

[C1 and deciding that

[C2 anyone

[C3 who suggests

this person in particular should do their own shopping next time ]

must be condemning someone ]

who must be disabled

is the kind of ridiculous over-projection ]

that makes trouble for real disability activism,

especially since the person

running the Jorts account

is also disabled.

<https://fail-fandomanon.dreamwidth.org/573343.html?thread=3499843487#cmt3499843487>

Eng137.

Will say, though,

[C1 the strange, seemingly genuine *anger*

[C2 that the mere fact

[C3 *Avatar* is the highest-grossing movie of all time ]

can still generate among a certain subset of extremely online nerds ]

is kind of funny. ]

[https://old.reddit.com/r/HobbyDrama/comments/z067ox/hobby\\_scuffles\\_week\\_of\\_november\\_21\\_2022/ixr6jfi/](https://old.reddit.com/r/HobbyDrama/comments/z067ox/hobby_scuffles_week_of_november_21_2022/ixr6jfi/)

Eng138.

[C1 This idea

[C2 that the devil

[C3 you know ]

is better than the devil

you don't ]

is fantastic! ]

[https://old.reddit.com/r/codexinversus/comments/xvfltt/the\\_zebubim\\_the\\_flypeople/irykthf/](https://old.reddit.com/r/codexinversus/comments/xvfltt/the_zebubim_the_flypeople/irykthf/)

Eng139.

[C1 And saying

[C2 that the thousands of people

[C3a who pack megachurches

to worship a Jesus

who hates gay people ]

[C3b and give money

[C4 they can't spare ]

to charlatans ]

are engaging in necessary practices of ritual and community ]

does harm to the world.] (DeBoer 2022f).

Eng140

[C1 Teaching them

[C2 that pressing a few buttons

[C3 to get an image ]

is equal to learning to draw ]

is literally taking away that gift. ] <https://twitter.com/FalconeerDev/status/1604382612717539330>

Eng141.

I love New York, honestly and truly,

[C1 but the law

[C2 where somebody has

to explain every year

how a convenience store

[C3 that might even have a cat ]

is unique ]

gets old]

<https://forums.somethingawful.com/showthread.php?threadid=3918745&userid=0&perpage=40&pagenumber=2123#post528768264>



Eng142.

Her beliefs are her own and not really any of our business,  
but why would we want

[C1 someone

[C2 who thinks  
women

[C3 who look like my fiancée ]

are ugly ]

to be at our wedding? ]

[https://old.reddit.com/r/AmltheAsshole/comments/101b5pe/aita\\_for\\_telling\\_my\\_sister\\_not\\_to\\_use\\_skin\\_cream/](https://old.reddit.com/r/AmltheAsshole/comments/101b5pe/aita_for_telling_my_sister_not_to_use_skin_cream/)

Eng143.

[C1 An investing rule of thumb like

[C2 “if anyone

[C3 pitching an investment ]

ever uses the word ‘trillion,’

hang up” ]

would probably serve most people reasonably well. ]

<https://www.metafilter.com/197827/Trillions-of-Dollars>

Eng144.

[C1 The fact

[C2 that a book

[C3 starring a robin, an owl and a bunny rabbit ]

manages

to be both sexist and classist ]

almost makes

me think

Mr Woodall deserves some sort of prize.]

<https://www.goodreads.com/review/show/1038870030>

Eng145.

In his cutting review of *The Waste Land*, then,

[C1 Lucas’ comment

[C2 that “a poem

[C3 that has to be explained in notes ]

is not unlike a picture with

‘This is a dog’

inscribed beneath” ]

must have been particularly stinging to Eliot.] (Jackson 2022)

Eng146

[C1 The fact

that the genius cannot get health care

[C2 while the hacks

[C3 who stole his ideas ]

can do anything

they want ]

exposes the supposed meritocracy of capitalism. ]

<https://forums.somethingawful.com/showthread.php?threadid=3898382&userid=0&perpage=40&pagenumber=1561#post529184608>

Eng147.

[C1 To say that

[C2 the only reason

[C3 animals kill and eat other animals in the wild]

is because

we kill and eat animals ]

is utterly ridiculous.]

<https://www.youtube.com/watch?v=qlbvN6Jcqp4>

Eng148.

[C1 The number

[C2 I've seen

claim that

cisgender female celebs

[C3 who have had well-documented pregnancies ]

are actually trans ]

is astounding.]

<https://forums.somethingawful.com/showthread.php?noseen=0&threadid=3919233&perpage=40&pagenumber=251#post529345251>

Eng149.

[C1 (A world

[C2 where the normal way

[C3 to consume tobacco ]

involved

having

to roll the cigarettes yourself ]

would have less smoking addicts.) ]

[https://old.reddit.com/r/slatestarcodex/comments/10nqaco/on\\_not\\_getting\\_contaminated\\_by\\_the\\_wrong\\_obesity/j6f4o97/](https://old.reddit.com/r/slatestarcodex/comments/10nqaco/on_not_getting_contaminated_by_the_wrong_obesity/j6f4o97/)

Eng150.

The belief

that the only way

to support an author

is to leave a review

needs to fucking die.

<https://twitter.com/therealzevgood/status/1622015169063706626>

Eng151.

the argument

that all of the children

bright is attempting to groom

might get mad if you take it down

is wild to me

<https://forums.somethingawful.com/showthread.php?noseen=0&threadid=3664805&perpage=40&pagenumber=265#pti36>

Eng152.

The question of

how the capacity

to calculate pragmatic inference

(co)evolved

is central

(Wittenberg 2023, CARTA talk)

Eng153.

Corridor's tech bro spiel

that traditional animation

that requires a team of incredibly skilled people drawing every frame

is somehow in need of 'democratising'

is straight up offensive.

[https://old.reddit.com/r/HobbyDrama/comments/11cjal9/hobby\\_scuffles\\_week\\_of\\_february\\_27\\_2023/jayk12y/](https://old.reddit.com/r/HobbyDrama/comments/11cjal9/hobby_scuffles_week_of_february_27_2023/jayk12y/)

Eng154.

The principles

that allow

each universal

discussed below

to influence and affect second language acquisition

occur and reoccur at each level. (Student essay)

Eng155.

The only time

what

we accomplish in the real world

really matters to us

is when we die

[https://old.reddit.com/r/slatestarcodex/comments/11pqxb6/my\\_unsolvable\\_dilemma/jc4m14v/](https://old.reddit.com/r/slatestarcodex/comments/11pqxb6/my_unsolvable_dilemma/jc4m14v/)

Eng156.

The idea

that mimesis, the desire

to ape other people,

drives culture

was propounded by Girard.

<https://freddiedeboer.substack.com/p/some-reasons-why-smartphones-might/comment/13399213>

Eng157.

The fact that

so many conditions  
that seemingly have no connection  
are related to autism

make

me think

that autism

(which for the purposes of this comment will refer exclusively to the

"reads esoteric blogs better than people"

autism rather than the

"cannot form a coherent sentence"

autism,

which may or may not be the same condition)

is less an actual condition and more just a result of

adapting to many small, sometimes difficult to describe dysfunctions.

<https://astralcodexten.substack.com/p/why-do-transgender-people-report/comment/13684826>

Eng158.

Basically the claim

that Takeshi Shudo wrote on his blog

that a script about

a T. rex fossil coming to life and being sold for thousands of dollars

[MISSING]

was a mistranslation.

[https://old.reddit.com/r/IcebergCharts/comments/11us2y0/pokemon\\_controversy\\_theories\\_and\\_obscure\\_media/jcslda6/](https://old.reddit.com/r/IcebergCharts/comments/11us2y0/pokemon_controversy_theories_and_obscure_media/jcslda6/)

## Appendix C: Emoji

Emoji1:

Happy Pollinator Week! 🐝🦋🐝

(email)

Emoji2:

  **Frogs in hats**     
@OweeeeenDennis

Creator of [#InfinityTrain](#), on iTunes and other services. I post frogs in hats.  
Mastodon: [@oweeeendennis@socel.net](mailto:@oweeeendennis@socel.net)

<https://twitter.com/oweeeendennis>

Emoji3:

Emoji4:

♥️🍷🍷[username]🍷🍷♥️

Emoji5:

Emoji6:



Emoji7:

✨🐱💖🎵four tornadoes🎵💖🐱✨

<https://bunjywunjy.tumblr.com/post/660984295605878784/four-tornadoes>

Emoji8:



Emoji9:

We are tired 🤔 of UC breaking the law 🚔🚔🚔

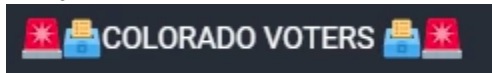
[https://old.reddit.com/r/UCSD/comments/yv1zkg/strike\\_copypasta/](https://old.reddit.com/r/UCSD/comments/yv1zkg/strike_copypasta/)

Emoji10:

🍄🌿🌙 Lonely Forest Night 🌙🌿🍄 (A.I. Generated Animation)

<https://www.youtube.com/watch?v=1kV9mh5z5s0>

Emoji11:



<https://imgur.com/gallery/6mzrgfK>

Emoji12

🏖️🌊🎉 BEACH PARTY AND RALLY 🎉🌊🏖️  
(UCSD strike email)

Emoji13 (ABACABA)

📢🎉📢 **Announcing MetaFilter Events** 📢🎉📢

<https://metatalk.metafilter.com/26199/---Announcing-MetaFilter-Events--->

Emoji 14

🌻🌸🌻 CURSOR GARDEN 🌻🌸🌻  
(online meeting announcement)

Emoji15

⚠️ Warning: do not use Hive Social 🐝👉

<https://twitter.com/dynamicsymmetry/status/1598330367374680064>

Emoji16

Have a dadjoke lol instead 🤔👤🤔👤🤔

[https://old.reddit.com/r/AmItheAsshole/comments/zje9rl/aita\\_for\\_telling\\_my\\_nephew\\_he\\_cant\\_be\\_a\\_bean\\_when/izvdz1e/](https://old.reddit.com/r/AmItheAsshole/comments/zje9rl/aita_for_telling_my_nephew_he_cant_be_a_bean_when/izvdz1e/)

Emoji17/18

Tempests in teapots brewed and cooled by now. 🤪😬🌀⚡🌀😬🤪



<https://www.blogger.com/comment.g?blogID=35115061&postID=1956365976844683383&isPopup=true&bpli=1&pli=1>

Emoji19



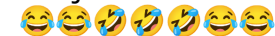
(text message)

Emoji20

That's fantastic! ❤️🐓🐓🐓🐓❤️

[https://old.reddit.com/r/bestofbirdbuddy/comments/zzb3cy/jealous\\_yard\\_bird\\_lol/j2b08xj/](https://old.reddit.com/r/bestofbirdbuddy/comments/zzb3cy/jealous_yard_bird_lol/j2b08xj/)

Emoji20



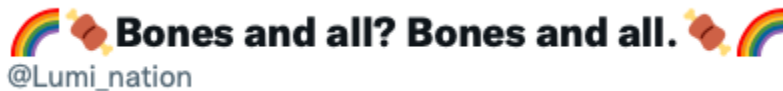
[https://old.reddit.com/r/flatearth/comments/106804u/flat\\_earth\\_arguments\\_continue\\_to\\_be\\_illogical/j3h0nss/](https://old.reddit.com/r/flatearth/comments/106804u/flat_earth_arguments_continue_to_be_illogical/j3h0nss/)

Emoji21



[https://twitter.com/Nova\\_Deluxe](https://twitter.com/Nova_Deluxe)

Emoji22



[https://twitter.com/Lumi\\_nation](https://twitter.com/Lumi_nation)

Emoji23

I LOVE LEAN!!!!!! 🟪🟪🥤🟪🟪

[https://old.reddit.com/r/UCSD/comments/10cofl6/why\\_is\\_it\\_purple/j4gvpjj/](https://old.reddit.com/r/UCSD/comments/10cofl6/why_is_it_purple/j4gvpjj/)

Emoji24



[https://twitter.com/Fuzzy\\_Fuzzbutt](https://twitter.com/Fuzzy_Fuzzbutt)

Emoji25

Happy Bird Buddy from Central Ohio. ❄️🐦❄️

[https://old.reddit.com/r/bestofbirdbuddy/comments/10iof8j/happy\\_bird\\_buddy\\_from\\_central\\_ohio/](https://old.reddit.com/r/bestofbirdbuddy/comments/10iof8j/happy_bird_buddy_from_central_ohio/)

Emoji26

🇺🇸🌻☆ **Mattathias** ☆🌻🇺🇸  
@MatthiasRider

<https://twitter.com/MatthiasRider>

Emoji27

if I remember correctly, >! humans are used as bricks !<.

[https://old.reddit.com/r/printSF/comments/10q8ubh/im\\_looking\\_for\\_sf\\_books\\_with\\_fle shy\\_architecture/](https://old.reddit.com/r/printSF/comments/10q8ubh/im_looking_for_sf_books_with_fle_shy_architecture/)

Emoji28



(text message from a friend)

Emoji29

🇺🇸🐼 **Antifa Trash Panda** 🐼🇺🇸  
@kittystryker

<https://twitter.com/kittystryker/status/1624204612298477568>

Emoji30

Riding the Time-Travel Train🚂🌈I Immersive Experience(4K)

<https://www.youtube.com/watch?v=D5AvjrXZ6Zk>

Emoji31

🌞🌈🌕COVER REVEAL🌕🌈🌞

<https://twitter.com/authorjessowen/status/1548438596457115649>

Emoji32

❤️😍SO CUTE😍❤️

<https://www.youtube.com/shorts/NhRZq-vp2Y4>

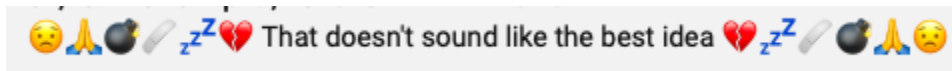
Emoji33



[https://old.reddit.com/r/UCSD/comments/11sxbir/seventh\\_dorm\\_tap\\_water/jcfyy51/](https://old.reddit.com/r/UCSD/comments/11sxbir/seventh_dorm_tap_water/jcfyy51/)

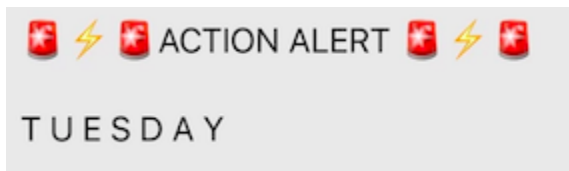


Emoji34/35



<https://www.youtube.com/watch?v=IdB-N03WUbo>

Emoji36





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NEXT UP WE WILL  
DISCUSS THE TOPIC WITH  
SOMEONE WHOSE JOB IS  
TO BE A WELL RESEARCHED  
AND RESPECTED EXPERT  
IN THE AREA



AND IN THE  
INTEREST OF  
BALANCE WE  
WILL ALSO TALK  
TO AN IDIOT



@twisteddoodles



1



26



150

**Scottish Dirk**

@BidenHarrisWH



Replying to @\_\_Paul\_G\_\_ and @TheRickWilson

A really sweet take on

👉👉 CNN 👈👈



Search Twitter



Log in

Use app

... ahead of expected 2024 announcement

75

66

48

**GORT**

@GORT88



Replying to [@AshleyRParker](#) [@Dawsey1](#) and [@michaelscherer](#)

Good, that's 3 more names we can add to the Trimp [sic] Losers List.

[==\*==]

5:12 PM · Nov 14, 2022 · Twitter for Android





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Use app



**Atticus Finch** @Atticus5991... · 14h



This is so vicious it's illegal in 19 states.



**Liz Cheney** @Liz\_Cheney · 14h

You're welcome, @KariLake.  
twitter.com/karilake/statu...



54



71



1,352



**Matthew J. Little**

@mlittle2010924



Replying to [@Atticus59914029](#)

\*reads Ms. Cheney's comment\*

Damn.....

6:50 PM · Nov 14, 2022 · Twitter Web App

1 Like



    **Jasmine Wolfe**      
407.5K Tweets



Follow

    **Jasmine Wolfe**      
@FireyTopaz

Progressive, atheist, cat lover. I'm also on Mastodon 😊  
MysticaRose@mstdn.social



📍 Irving, TX 📅 Joined January 2010

8,476 Following 7,774 Followers

Tweets

Tweets & replies

Media

Likes



    **Jasmine Wolfe**     Retweeted



 HAPPY BIRTHDAY!

Please join us in wishing Nick Clooney a very happy birthday! He is 89 years young today 🙌

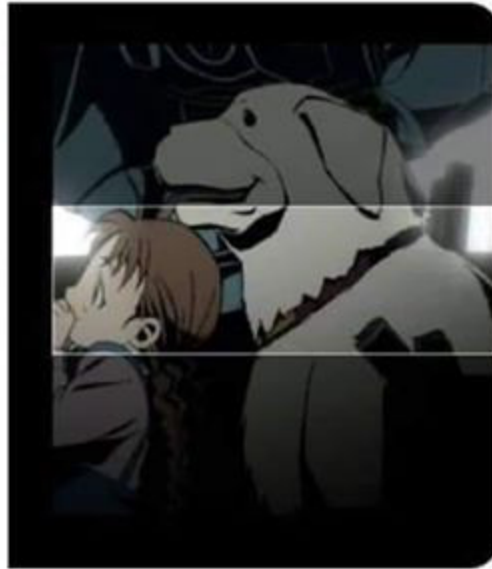
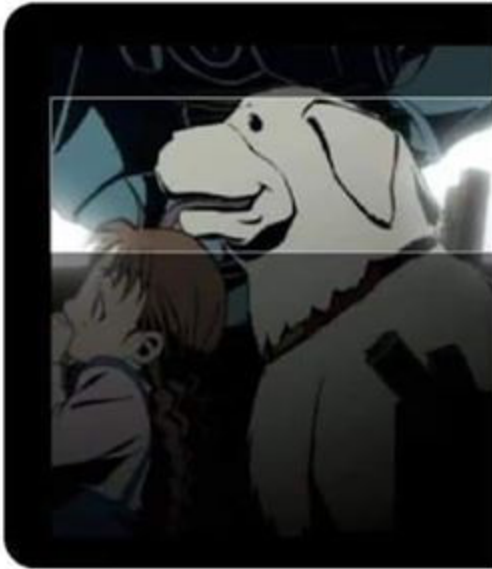




†🌀 amos says BLM 🌀†

@Amoviet1

ugh i can't get them both to fit in my banner



†🌀 amos says BLM 🌀†

@Amoviet1

nvm figured it out



**eros** 🇧🇷 @hvtntlow · 11h



Replying to @blekiscool and @slaypublican

next thing u know kids will think they're straight because they've been indoctrinated into a cult of heterosexuality

📊 24.5K 💬 5 ↺ 25 ❤️ 1,960 ↗



**SlaYeR** ✓ @SlaYeR\_RL · 6h



bro what

📊 10.2K 💬 9 ↺ 2 ❤️ 9 ↗



Show replies



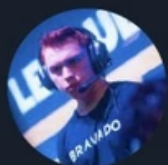
🌻💖 **Centibug** 💖🌻 @Centibug12 · 7h



Replying to @blekiscool and @slaypublican

Im fine with heterosexuality as long as its not near kids. I dont want them thinking its okay to be hetero

📊 11.9K 💬 2 ↺ 11 ❤️ 751 ↗



**SlaYeR** ✓ @SlaYeR\_RL · 6h



ur joking right

📊 8,592 💬 12 ↺ ❤️ 4 ↗





🍁🍁 BIRDJAY 🍁🍁

@humdrumvee

logistically, i knew michelangelo's david was 17 feet tall. somehow that knowledge does not translate as well as seeing this image:



<https://imgur.com/gallery/6zeAAiF>

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