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Finding Meaning in Silence:
The Comprehension of Ellipsis

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

in

Language and Communicative Disorders

by

Josée Poirier

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2009

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The Dissertation of Josée Poirier is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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2009

DEDICATION

In loving memory of David Swinney

A mentor whose influence, I hope, is discernible in this work

EPIGRAPH

Education's purpose is to replace an empty mind with an open one.

- Malcolm Forbes

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ABSTRACT OF THE DISSERTATION

Finding Meaning in Silence:
The Comprehension of Ellipsis

by

Josée Poirier

Doctor of Philosophy in Language and Communicative Disorders

University of California, San Diego, 2009
San Diego State University, 2009

Professor Tracy Love, Co-Chair
Professor Lewis Shapiro, Co-Chair

This dissertation examines the real-time processing and interpretation of Ellipsis. Ellipsis refers to a family of elements that are absent from the input but crucial for the overall interpretation of a sentence. Ellipsis therefore offers a unique opportunity to study the form–meaning correspondence in language comprehension, since the intended meaning is transmitted without recourse to a fully-fledged signal. The studies in this dissertation aimed to determine the meaning that is attributed to silent constituents in auditory sentence comprehension, with an emphasis on Verb-Phrase Ellipsis and Sluicing.

Furthermore, the time-course of interpretation computation was examined using a methodology sensitive to online processing (Cross-Modal Priming).

Chapter 2 investigated the processing of unaccusative and unergative verbs in Verb-Phrase Ellipsis (e.g.: The dog disappeared in the crowded street fair and the child did too). Chapter 3 examined the interpretation of Sluiced sentences (The handyman threw a book to the programmer, but I don't know which book). Chapter 4 presents neuropsychological evidence on the recovery of meaning in Verb-Phrase Ellipsis. Taken together, these studies indicate that ellipsis is interpreted in real time, as the sentence unfolds, by retrieving the mnemonic representation of the antecedent (the intended meaning provided in the early part of the sentence). The parser only reactivates the syntactically-defined antecedent; no more material than necessary is reconstructed at the ellipsis. However, the meaning assigned to the ellipsis may differ from the antecedent: in Sluicing, the parser might assign a partial or temporarily mismatching interpretation to the ellipsis. Additionally, these findings point to a role of parallelism expectations in the timely postulation and resolution of ellipsis.

Lastly, the linguistic properties of Ellipsis were exploited to test specific hypotheses on language representation and processing in normal and disordered language. For instance, Chapter 2 aimed to determine whether traces are represented as silent syntactic phrases during processing and Chapter 4 evaluated aphasic patients' ability to process, in real time, a complex but canonically-ordered construction.

CHAPTER 1

Introduction

Elliptical constructions are sentences in which a part is 'missing' but readily understood. For example, the second clause in '*Juliet likes brownies and Dave, apple pies'* does not contain a verb. Yet, comprehenders unambiguously understand that Dave likes apple pies. How do comprehenders extract the intended message from an informatively incomplete signal? This question has generated much interest in linguistics and in psycholinguistics, as it may shed light on the relation between form and meaning. Although the conclusion that comprehenders must 'fill in' the missing pieces comes naturally, there exists little experimental evidence to directly support this assumption or to determine the point in time at which the 'filling-in' would occur. This dissertation aimed to fill this gap in the literature by examining, in real time, how ellipsis receives meaning. To do so, I exploit the properties of different types of ellipsis and measure activation of various sentence constituents while sentences are unfolding over time.

In this first chapter, I introduce the linguistic machinery and experimental background on ellipsis and its interpretation against which the experimental studies in Chapters 2-4 are set. After presenting these chapters based on my empirical work, the final Chapter 5 attempts to integrate the findings from the experimental studies and will present some unresolved issues that future work should address. The findings of this dissertation contribute to our understanding of ellipsis detection and meaning assignment.

The Linguistics of Ellipsis

Ellipsis describes a family of elements that is absent from the spoken (or written) sentence but that carries meaning. Consider (ellipsis indicated by Ø):

[1] Juliet likes brownies and Dave, $Ø_V$ apple pies. Gapping

[2] Greg bought a new car and Elena did $Ø_{VP}$ too. Verb-Phrase Ellipsis

[3] Miriam saw a new play on Broadway Sluicing
but I don't know when $Ø_{IP}$.

Important properties differentiate ellipsis types, one of which is the categorical identity of the elided phrase. For instance, Gapping elides a lexical category, a verb (V); Verb-Phrase Ellipsis involves the elision of a phrasal category, a verb phrase (VP); and Sluicing involves the reconstruction[1] of an entire clause (IP). Each of these, then, can be differentiated by the "grain size" of the elided material. Regardless of the categorical identity or grain size of the elided material, the missing element carries no ambiguity or vagueness; the meaning of the ellipsis appears to be easily recovered. Indeed, adults perform at an accuracy level of 97% in self-paced reading and in a sentence verification paradigm testing comprehension (Bélanger, 2004).

Ellipsis is unambiguously understood because its interpretation is constrained. For instance, [1] must mean "Dave likes pies" though there is no overt indication of the verb's meaning, suggesting that recovery of elided material is semantically constrained. In fact, all types of ellipsis are subject to a Parallelism constraint that forces the ellipsis clause to parallel, in meaning, the previous clause (the *antecedent* clause). It is by virtue of this constraint that the meaning in [1] can be reconstructed correctly: Parallelism

[1] Reconstruction is used throughout the text to refer to the recovery of the elided phrase's meaning and does not necessarily imply the construction of syntactic structure at the ellipsis.

ensures that the missing part of [1] is not taken to mean, for example, that ‘Dave baked pies’, or [3] to mean that ‘I don’t know when John saw a new play’. This demonstrates a remarkable capability of the sentence processor: it can complete missing information by leaning on the first clause, even though this information is not adjacent to the missing part and is long gone in the temporal stream. Thus, elided phrases are interpreted as their non-elided counterparts (their *antecedent*, underlined below) in the first clause:

[1b] Juliet <u>likes</u> brownies and Dave [likes]$_{V}$ apple pies.

[2b] Greg <u>bought a new car</u> and Elena [bought a new car]$_{VP}$ too.

[3b] <u>Miriam saw a new play on Broadway</u> but I don’t know when
[Miriam saw a new play on Broadway]$_{IP}$.

The role of syntactic parallelism in ellipsis interpretation has also long been discussed. Syntactic parallelism has been used to argue for the presence of syntactic structure at the elision site (e.g., Hankamer & Sag, 1976; Merchant, 2001; see also Fiengo & May, 1994). By contrast, semantic accounts (ellipsis as a proform or pronoun-like element; e.g., Dalrymple, Shieber, & Pereira, 1991; Hardt, 1993) have claimed that the elided material has no syntactic structure at the elision site; therefore, no effects of syntactic structure are predicted at the ellipsis. One last account offers a middle ground, claiming that the presence of internal syntactic structure at the elision site depends on the

discourse in which it appears (Kehler, 2000). Specifically, this analysis associates the requirement for syntactic structure to resemblance relations, in which two clauses or sentences contrasted or put in parallel (e.g.: *Gary loves animals. Betty is fascinated by insects*.)

Hence, the existence of syntactic effects at the ellipsis can help to distinguish among these accounts. The most well-documented of these effects regards the acceptability of syntactic mismatches between the antecedent and the elided phrase. For instance, certain accounts refute the acceptability of elliptical constructions that have syntactically mismatching antecedents (Chung, 2005; Merchant, 2008). In contrast, linguistic and psycholinguistic evidence is mounting on the acceptability of nonparallel elliptical structures (under certain conditions), suggesting that acceptability is not categorical but graded in nature (Kehler, 2000, 2002; Kertz, 2008; Frazier & Clifton, 2006; Arregui, Clifton, Frazier, Moulton, 2006). Across theoretical lines, it is agreed that ellipsis extracts meaning from previously encountered material in the first clause and that ellipsis and its antecedent share categorical identity (verb, verb phrase, clause, etc.).

The Psycholinguistics of Ellipsis

Ellipsis is a widely common linguistic phenomenon, appearing in spoken language in about 7.5% of utterances (Alcántara & Bertomeu, 2005). Although ellipsis is frequently encountered, it is difficult for the comprehension system to predict where it will appear or what its category, structure (if any) and meaning will be. This dissertation

explores two aspects of ellipsis resolution: the postulation of an ellipsis and the assignment of meaning to the implicit phrase.

Detection of the Ellipsis

In ellipsis, there is no overt cue that unambiguously signals the presence of an elided constituent. For instance, in the gapping example reproduced below, the ellipsis is detected when the direct object (*apple pies*) in the elliptical clause (EC) is processed, where a verb would be expected:

[4] Juliet likes brownies and Dave, Ø apple pies.

Yet, neurophysiological data indicate that comprehenders notice the 'missing' verb as early as possible (namely, within 100-300ms of processing the post-verbal segment; Kaan, Wijnen, & Swaab, 2004; Streb, Hennighausen, & Rösler, 2004; Callahan, Nicol, Love, & Swinney, 2007). Similarly, several studies using cross-modal priming (the paradigm of choice in the studies described in Chapters 2-4) have demonstrated that the ellipsis is resolved at the elision site (*did too*) in verb-phrase ellipsis (VPE; Shapiro & Hestvik, 1995, Exp. 1; Shapiro, Hestvik, Lesan & Garcia, 2003). In other words, the processor reacts promptly to the unexpected covert phrase.

However, a seemingly inconsistent result is reported in a cross-modal priming study in which VPE resolution is observed some 600ms post-ellipsis (Shapiro & Hestvik, 1995, Exp. 2). It was proposed that the delay may be due to the conjunction of subordination 'because' (*The policeman defended himself because the fireman did Ø too*). The conjunction establishes a cause–effect relation between the clauses, a semantic relation that draws out the time course of processing in the elliptical clause.

Parallelism Effects

Much attention has recently been devoted to the so-called parallelism effects in non-elliptical, coordinated sentences. The effect refers to the facilitation in processing a second conjunct when it parallels the first on some syntactic dimension such as voice, attachment site or thematic structure.[2] For example, the second conjunct (*the short thug hit Sam*) is read faster in [5a] than [5b]:

[5a] [The tall gangster hit John]$_{\text{Active}}$ and [the short thug hit Sam]$_{\text{Active}}$.

[5b] [John was hit by the tall gangster]$_{\text{Passive}}$ and [the short thug hit Sam]$_{\text{Active}}$.

[Examples from Frazier et al..et al.., 1984]

[2] A parallelism effect has also been found within production but also from comprehension to production. See Pickering & Ferreira, 2008 for a recent and exhaustive review.

That is, the voice match in [5a] speeds up the processing of the second conjunct (Frazier, Taft, Roeper, Clifton & Ehrlich, 1984). This effect has been explained as a processing cost for structures that violate the expectation of parallelism – namely, for nonparallel structures (Frazier et al., 1984; Frazier, Munn & Clifton, 2000; Pickering, Branigan, Cleland & Stewart, 2000; Apel, Knoeferle & Crocker, 2007; Knoeferle & Crocker, in press. See also Dubey, Sturt & Keller, 2005 for corpus data on the phenomenon). This expectation arises from processing the conjunction and results in the sustained activation of first-conjunct material in the second conjunct (Callahan, Shapiro & Love, submitted). This material may then be used as a template to guide the parsing of the second conjunct. In cases where the second conjunct is parallel to the first, facilitation results; for nonparallel conjuncts, processing costs are incurred.

The facilitation effect seems, however, to be restricted to sentences conjoined by parallelism-implying conjunctions (e.g.: *and*, *while*; Knoeferle, 2007). For instance, the conjunction *but* does not yield a parallelism effect, since it establishes a different semantic relation between the conjuncts (Knoerferle, 2007). Thus, no parallelism is expected from processing 'but'. By extension, the conjunction of subordination *because*, which does not imply parallelism (but does imply a cause-effect relation), would also not induce facilitation effects. Returning to the discrepancy in the time course of ellipsis resolution referred to earlier, early effects were observed in *and*-coordinated sentences whereas the later effect was found in *because*-conjoined construction. In other words, parallelism expectations are associated with timely ellipsis postulation and resolution.

Parallelism effects have similarly been reported in elliptical constructions; in fact, the processing advantage for parallel structures has been argued to be even stronger in elliptical structures (Fox, 2000; Kehler, 2000), suggesting that ellipsis draws upon parallelism in a way that nonelliptical sentences do not. Experimental evidence has repeatedly demonstrated that an elliptical clause is processed more quickly following a parallel antecedent (Tanenhaus & Carlson, 1990; Mauner, Tanenhaus & Carlson, 1995; Arregui et al., 2006; Dickey & Bunger, under review):

[6] Someone had to [take out the garbage]$_{\text{Active}}$. But Bill refused to [Ø]$_{\text{Active}}$. Parallel

[7] The garbage had to [be taken out]$_{\text{Passive}}$. But Bill refused to [Ø]$_{\text{Active}}$. Nonparallel

[Examples from Tanenhaus & Carlson, 1990]

In example [6], the antecedent and the ellipsis match syntactically: both clauses are in the active form. By contrast, the antecedent is in the passive voice in [7], creating a syntactic mismatch with the ellipsis. Participants responded faster to an end-of-sentence probe ('make-sense' sentence verification) after a parallel ([6]) sentence, compared to a nonparallel one ([7]). Participants' judgments were also more inclined to accept the probe as 'making sense' in the parallel than in the nonparallel condition (Tanenhaus & Carlson, 1990). In other words, elliptical sentences with a parallel antecedent were easier to process and overall preferred.

Antecedent Attribution

Early arguments originally proposed that the ellipsis received meaning via a mechanism that copied the antecedent at the elision site (Frazier & Clifton, , 2001). On this account, copying more structure (i.e., more complex vs. simpler antecedents) would induce higher computational costs. Subsequent work has repeatedly failed to find complexity effects in support of the copy operation (Frazier & Clifton, 2000, 2001, 2005; Martin & McElree, 2008). For example:

[8] Sarah [left her boyfriend last May]$_{VP}$. Tina did Ø too.

[9] Sarah [got up the courage to leave her boyfriend last May]$_{VP}$. Tina did Ø too.

[Examples from Frazier & Clifton, 2000]

Reading times for *Tina did too* did not differ significantly between the two constructions, although the antecedent in [8] is simpler (1 clause) than that in [9] (2 clauses). A reformulated copy mechanism was proposed (Copy-α; Frazier & Clifton, 2001), one that provided a cost-free means of copying syntactic structure.[3] Alternatively, the structure at the elision site may come from sharing the structure with the antecedent (Frazier & Clifton, 2005). In a structure-sharing view, the structure at the elision site may under

[3] The Copy- α mechanism was elaborated based on the lack of complexity effects. The question of whether there is syntactic structure at the ellipsis is thus reasonable to ask; its answer is still debated, but see Frazier & Clifton, 2001 for some arguments in support of the presence of syntactic structure at the elision site.

certain conditions undergo changes to ensure grammatical well-formedness of the elliptical clause and by consequence may differ from the antecedent. In sum, copy or structure-sharing mechanisms assume the presence of syntactic structure at the elision site.

By contrast, the absence of complexity effects may be interpreted as indicating that no syntactic structure is present at the ellipsis. This view has been defended in psycholinguistics on the basis of speed-accuracy trade-off (SAT) data that again, failed to find computational costs in retrieving from memory more complex antecedents (Martin & McElree, 2008).[4] The SAT findings were argued to be more consistent with a content-addressable memory pointer that would direct the parser to the antecedent's mnemonic representation. The lack of complexity effects still generates discussion on the mechanism underlying antecedent assignment. One related question it raises is *what meaning*, exactly, is assigned to an ellipsis.

Hints came from the literature on anaphora (pronouns, reflexives, traces) that antecedent selection is guided by syntactic constraints. In anaphora, a (nonelliptical) element also requires an antecedent to be interpreted:

[10] The boxer told the skier that the doctor for the team would blame him*
for the recent injury.

[4] Complexity did not affect speed of processing in any of the conditions tested in the multiple-experiment study. However, the number of noun phrases in the antecedent did negatively impact accuracy of interpretation. The authors attribute this decline to interference.

[11] The boxer told the skier that the doctor for the team would blame himself*
for the recent injury.

[Examples from Nicol, 1988]

To understand who *him* designates, the pronoun must be related to its antecedent – the noun phrase (NP) that refers to the same entity in the discourse as the pronoun (say, *boxer* in [10]). A cross-modal priming study demonstrated that the antecedent-pronoun link is established immediately, as the sentence unfolds (Nicol, 1988). That is, priming for the antecedent (faster reaction times to antecedent-related probes compared to control probes), which is interpreted as reflecting antecedent retrieval, was obtained at the offset of the anaphor (signaled by * above). In fact, both potential antecedents (*boxer* and *skier*) were found activated at the anaphoric site in [10], whereas only *doctor* was primed when the reflexive was substituted for the pronoun in the same sentences ([11]; Nicol, 1988). These results indicate that syntactic constraints guide antecedent retrieval such that only syntactically legal antecedents are re-accessed at the anaphor.

Similar mechanisms and constraints are believed to apply to ellipsis resolution. And here, cross-modal priming investigations of verb-phrase ellipsis (VPE) have shown that ellipsis also triggers the re-activation of its antecedent:

[12] The mailman [bought a tie]$_{VP}$ and the fireman [did too]$_{VPE}$,
according to the salesclerk.

In one study, priming for *tie* was probed at the elision site and shortly beforehand. Priming was only obtained at the *did too* position, indicating that *tie* – and, by inference, the antecedent VP – was retrieved from memory at the temporal point of the ellipsis (Shapiro et al., 2003, Exp. 3). By contrast, in the same sentences, the subject *mailman* was not observed activated at either position (Shapiro et al., 2003, Exp. 3). These results demonstrate that the antecedent is reactivated by the ellipsis. Furthermore, these findings indicate that syntactic constraints apply such that only the syntactically-defined antecedent (in this case, the subject-excluding VP) is retrieved, similar to anaphora.

However, a self-paced reading study reports that processing a Verb-Phrase Ellipsis involves subject reactivation. In this self-paced reading study, the recognition of a visual probe related to the subject (i.e., *renowned*) was faster in elliptical than in nonelliptical constructions (Koeneman, Bauuw, & Wijnen, 1998):

[13] The renowned judge severely criticized the jury, and the prosecutor was astonished. Probe = *Renowned*

[14] The renowned judge severely criticized the jury, and the prosecutor did Ø too. Probe = *Renowned*

Although these data are intriguing, it is difficult to interpret them for two reasons. One, the control sentences differed from the elliptical constructions on more than one

dimension. The control sentences ([13]) were indeed nonelliptical but also nonparallel (change of voice between conjuncts, from active to passive), whereas their elliptical counterparts were parallel ([14]). As mentioned above, non-parallelism is penalized in coordinated sentences and could have induced longer reaction times on the recognition task. Second, and more critically, the probes appeared at the end of the sentences, which leaves open the question of when, exactly, a potential subject reactivation would take place. For instance, it is unclear whether the subject would be retrieved at the same time its legal antecedent (the VP) is, or whether it would be re-accessed at a later point for integrative purposes.

To summarize, the processing system establishes the antecedent-ellipsis link in real time, which results in antecedent re-activation. Moreover, syntactic constraints guide the retrieval of material from memory by restricting the re-access to the syntactically-defined antecedent, thereby excluding additional phrases (such as the subject in VPE). On the flip side, it is unknown whether all elements within the syntactically-defined antecedent are re-accessed. In fact, there are indications that accuracy in interpretation decreases as the number of phrases in the antecedent increases (Martin & McElree, 2008), suggesting that some information from the antecedent may be lost during ellipsis resolution.

Ellipsis as an Investigation Tool

Each of the studies in this dissertation provides new insights into the comprehension of elliptical constructions. Their experimental findings are not limited to the processing of these linguistic structures, however. In effect, ellipsis was exploited in the present work to examine the general architecture and mechanisms of the processing system. This section outlines the specific theoretical issues on which this dissertation provides experimental insights.

Models of Language Processing

Models of language processing can be divided into two types: form-driven and constraint-based accounts. Form-driven models (e.g., Frazier, 1978; Frazier & Fodor, 1996) attribute a privileged status to syntactic information, giving it priority over other sources of information (semantics, preferences, probabilistics, etc.) in guiding the initial parse of the input. In contrast, no such exclusivity is recognized for syntax in constraint-based accounts (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994): all types of constraints are immediately considered to derive the most likely interpretation of the sentence (though on some accounts certain constraints, for example, frequency of use, takes precedence over others, for example, information from context). With the goal of informing these processing models, previous work has reported that semantic constraints on verbs do not restrict the initial parse (Shapiro & Hestvik, 1995). For instance, when

comprehending *The policeman winked his eye and the fireman did too*, the processor initially computes the reading of the fireman winking the policeman's eye, although this interpretation is unacceptable (Shapiro et al., 2003). The constraint that one can only wink one's eye (a semantic property of the verb) is temporarily ignored.

The Representation of Traces

Psycholinguistics imported the concept of a *trace* from theoretical linguistics to study the cognitive mechanisms underlying language processing. Consider the following example(trace represented with a *t*):

[15] The policeman talked to the boy$_i$ who the crowd accused _t_i_ of the crime.

A silent placeholder (the trace) is said to lie in the postverbal position, where the 'accusee' would typically appear. The trace must then be linked to its antecedent (*the boy*) to understand who is being accused. Psycholinguistic work has demonstrated that traces are processed much like other anaphora: the antecedent is reactivated postverbally, where a trace is postulated (Swinney, Ford, Frauenfelder and Bresnan, 1988 (reported in Nicol & Swinney, 1989); McElree & Bever, 1989; Osterhout & Swinney, 1993; Friedmann, Shapiro, Taranto & Swinney, 2008). Despite the evidence for cognitive operations taking

place when a trace is postulated, it is unclear whether traces are mentally encoded as (phonetically unrealized) syntactic phrases or whether they are a descriptive tool for linguistic theory that has no representational counterpart in processing. In the latter scenario, the verb itself is understood to directly re-activate its argument (*boy*) to designate it as the 'accusee' (the Direct Association Hypothesis; Pickering & Barry, 1991). Hence, the liaison between the verb and its argument may obtain without recourse to covert phrases.

Anaphoric Processing in Aphasia

Lastly, the difficulties of aphasic patients in comprehending sentences involving anaphora are well documented. Specifically, it was demonstrated that patients lag in re-accessing the antecedent of traces (such as [15], reproduced below; see Love, Swinney, Walenski, & Zurif, 2008).

[16] The policeman talked to the boy who the crowd accused _*t*_ of the crime.

One group of accounts of sentence comprehension in aphasia has argued that patients' deficits stem from the presence of argument displacement in the sentence (bringing *the boy* from the postverbal position to the front of the sentence in [16]) and the subsequent

need to interpret the trace (Grodzinsky, 1986, 2000; Zurif, 2000; Zurif, Swinney, Prather, Solomon & Bushell, 1993). The displacement factor is however conflated with others, such as the scrambling of the relative order of verbal arguments after displacement (*policeman*, *boy* and *crowd* in [16]) and the assignment of an antecedent to the trace. Ellipsis, on the other hand, can dissociate these factors. Specifically, ellipsis constructions may provide a means to tap into antecedent-assignment operations in the absence of argument scrambling.

Notes on Methodology

Two central questions this dissertation aims to answer are 'What gets reactivated at the ellipsis?' and 'When is ellipsis detected'? Unsurprisingly, not all methodologies are appropriate to address these issues. The Cross-Modal Priming paradigm (Swinney, Onifer, Prather & Hirshkowitz, 1979) provides a snapshot of lexical activation patterns during the unfolding of a sentence. The paradigm was selected for the investigations reported in this dissertation because it can provide information on what is activated at specific points in time.

In this dual-task paradigm, sentences are aurally presented to participants. At unpredictable intervals, comprehension questions are asked to encourage attention to the auditory stimuli. The second task requires participants to make a decision on visual probes. Two variants used in this dissertation include a lexical decision on strings of

letters (‘Is it a word of English?’) and a semantic decision on pictures (‘Is it alive?’). Accuracy and reaction times are recorded with millisecond precision. Probes are related to the word of interest (i.e., a noun phrase in the sentence) in the Related condition and unrelated to the sentence in the Control condition. Faster reaction times in the Related condition reflect a priming effect (Neely, 1977). A priming effect is interpreted as an indication of the prime’s activation (the noun phrase in the sentence) at that point in time. Because probes are strategically presented at relevant points during the unfolding of the auditory sentence, it is possible to track the activation of the noun phrase over time and relate these patterns to the properties of the sentence (e.g., the location of an ellipsis). Furthermore, this paradigm has been shown not to disrupt or modify the normal processing of the sentences (up until the presentation of the probe; see Nicol, Swinney, Love & Hald, 2006; Swinney, 1984). This technique thus taps into automatic, unconscious operations as they naturally apply during comprehension (Swinney, 1984). Therefore, Cross-Modal Priming was the ideal paradigm to test the experimental questions this dissertation was set to answer.

Outline of the Dissertation

This dissertation is composed of three experimental chapters (Chapters 2-4). Chapter 2 investigated the activation patterns associated with two verb types (and with traces) in Verb-Phrase Ellipsis. The experiments in Chapter 3 examined the computation of an interpretation in Sluicing, in which the antecedent is perhaps the most complex of

all ellipsis types. Chapter 4 examined the ability of individuals with aphasia to process ellipsis in real time. Chapter 5 discusses how the findings of Chapters 2-4 relate to and extend the current literature on ellipsis.

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CHAPTER 2

The Representation of Traces:

Evidence from Unaccusative Verbs in Verb-Phrase Ellipsis

Abstract

The theoretical concept of traces, silent elements of a sentence, was borrowed from linguistic theory to study sentence processing. Although traces are missing from the input/ output, evidence that traces are recognized by the processing system has accumulated. Yet, it is unclear if/how traces are represented mentally. In this study, we investigated the representational nature of (NP)-traces. We hypothesized that if traces are concrete (albeit phonetically unrealized) lexical components of a sentence, they would show the same behavior as their overt counterparts, reflexives. Using Cross-Modal Priming, we tested the online interpretation of trace-containing unaccusative verbs in Verb-Phrase Ellipsis constructions. We found evidence for the computation of the sloppy reading by unaccusative verbs, similarly to reflexives. However, the computation of the strict reading could not be confirmed. We conclude that the lexical properties of unaccusativity/unergativity immediately influence the computation of an interpretation in ellipsis. Furthermore, our findings suggest a role of parallelism expectations in the comprehension of covert material such as ellipsis.

For decades now, linguistic theory has successfully informed psycholinguistic work on the architecture of the processing system. Psycholinguists have utilized linguistic theory to conceptualize and formulate experimental questions, or to generate carefully controlled stimuli that tap into specific cognitive processes. Such stimuli include the extensively employed family of anaphora, which require reference to other elements of the sentence to be interpreted.

Traces as Anaphora

Traces are an especially interesting type of anaphor. Their existence must be inferred from context since traces are phonetically unrealized. Consider:

[1] a. The boy whom the girl kissed is my next-door neighbor.

b. The boy whom the girl kissed [$\text{trace}_{\text{boy}}$] is my next-door neighbor.

In sentence [1a], there is no explicit specification of who received the kiss, based on the regular pattern in English that the object of the verb appears postverbally. Yet, [1a] is unambiguously understood as ‘the girl kissed the boy’. Since the attribution of thematic roles—who did what to whom—by the verb to its arguments relies on their relative order, the absence of ‘the boy’ from its expected postverbal object position complicates thematic role assignment; the relation between the verb and its out-of-position argument has to be established via a silent placeholder (the trace) that links ‘the boy’ with the role

of recipient of the kiss. In short, traces are devices used to explain the seemingly problematic liaison of the verb and its nonadjacent arguments.

Based on the assumption that there is a transparent relation between linguistic theory and language processing, psycholinguists have utilized traces as a means to investigate the processing of verb-argument relations. Fortunately, this assumption has proven fruitful. For instance, it has been repeatedly shown that the antecedent of a trace is reactivated at (or slightly later than) its temporal location of the covert anaphor in the sentence (Nicol & Swinney, 1989). For example, in sentence [2], activation of *boy* is observed at the offset of *kissed*:

[2] The boy that the girl kissed [$\text{trace}_{\text{boy}}$] is my next-door neighbor.

The effect is selective—only the correct antecedent is re-accessed—and instantaneous once the trace is detected. Hence, these activation patterns indicate that the relation between the verb and its displaced argument is established in real time, as the sentence unfolds. However, the mechanism underlying the computation of the relation is still debated. More precisely, the necessity for a silent anaphor has been questioned, since the processing evidence can also be explained without recourse to traces. For instance, the Direct Association Hypothesis (DAH; Pickering & Barry, 1991) suggests that the displaced argument is directly linked to the verb for thematic role assignment purposes. When the verb (an assigner) is processed, its displaced argument (the assignee) is re-accessed to receive its role. Crucially, there is no intermediary between the verb and the

argument. Hence, a traceless account is more parsimonious than a trace-based account, since it requires one fewer assumption (a trace).

In sum, the construct of a trace as imported from theoretical linguistics has processing correlates; for instance, the displaced argument/antecedent of the trace is re-activated postverbally. However, the necessity to postulate a silent anaphor (that is, that traces are mentally represented) is unclear. The goal of this study was to determine whether traces are mentally represented as (phonetically unrealized) anaphora. If so, we hypothesized that traces would behave similarly to their overt counterparts, reflexives (e.g.: himself). (Reflexives and traces share distributional properties and consequently, are analyzed as overt/covert equivalents in syntactic theory (Government and Binding Theory; Chomsky, 1981). We opted to exploit Verb-Phrase Ellipsis as a means to compare the online processing of traces to that of reflexives. The next section presents the pattern of behavior observed with reflexives in Verb-Phrase Ellipsis constructions, which served as the basis for comparison with traces.

Processing anaphora in Verb-Phrase Ellipsis

Verb-Phrase Ellipsis (VPE) is a common sentence structure in which a part is missing and must be reconstructed from a previous clause. In [2], for example, the fireman also bought a tie, but a VPE (*did too*) substitutes for the verb phrase:

[3] The policeman [bought a tie] $_{VP}$ and the fireman [did too]$_{VPE}$
according to the salesclerk.

To understand what the fireman did, the ellipsis must be linked to its antecedent, the verb phrase (VP) '*bought a tie'*. In processing terms, the parser must detect the ellipsis and identify and retrieve its antecedent. Previous work from Shapiro and colleagues (Shapiro & Hestvik, 1995; Shapiro, Hestvik, Lesan, & Garcia, 2003) has shown that the antecedent VP is reactivated as soon as the VPE is detected (at the offset of the bare auxiliary *did*). Importantly for our study, the subject of the antecedent clause (*policeman*) is <u>not</u> reactivated at the elision site. Thus, only the syntactically-defined antecedent (the VP) is re-accessed to interpret VPE, not all arguments of the verb (see also Koeneman, Baauw & Wijnen (1998) for a related proposal) . This conclusion is crucial to interpret the activation patterns when the antecedent contains an anaphor such as a reflexive:

[4] The policeman$_i$ [defended himself$_i$]$_{VP}$ and the fireman [did too]$_{VPE}$,
according to the salesclerk.

This sentence has two potential interpretations: that the fireman defended the fireman (sloppy reading) or the fireman defended the policeman (strict reading). The ambiguity in interpretation arises from the presence of an anaphor (the reflexive *himself*) within the antecedent. When the VP is reconstructed at the VPE, the referent-seeking reflexive can be linked to a local antecedent, *fireman*, or can carry over its relation with its previous antecedent, *policeman* (see Shapiro et al., 2003 for the detailed computational steps). This interpretive ambiguity is reflected in processing, where both

subjects *policeman* and *fireman*) are found activated at the elision site.[1] In other words, the strict and the sloppy readings are computed in real time. In short, the presence of an anaphor in the antecedent VP results in the computation of both readings at the VPE. In the current study, we thus probed for the strict and sloppy readings in VPE using a trace as the antecedent-included anaphor.

Selecting a trace

The choice of VPE as a vehicle to be studied required the presence of a trace in the antecedent VP. We elected to utilize unaccusative verbs (UA) since they are associated with a trace. These predicates only have one argument, a subject (*The dog disappeared.*). However, the verb's argument is claimed to have originated postverbally, in an object position [5a], and then moved to appear as a subject [5b]:

[5]	Subject - Verb - Object	Syntactic positions
	Agent - Verb - Theme	Thematic Roles
	a. [Ø] disappeared the dog.	Sentence generated
	b. [The dog]$_i$ disappeared[*trace*$_i$].	Sentence heard

[1] Note that in 'The policeman winked his eye and the fireman did too', the fireman cannot wink the *policeman's* eye. Still, the strict reading is computed even when if the verb's properties prohibit it (Shapiro et al., 2003). So both readings are computed online, at the VPE, whether or not both interpretations are acceptable, and even if the sloppy reading is preferred offline (in fact, it has been observed that the strict reading can be difficult to generate offline (Fiengo & May, 1994). This observation is important for the current study: with unaccusative verbs, only the sloppy interpretation is acceptable. Nonetheless, this offline judgment should not prevent the computation of the strict reading at the VPE.

This syntactic analysis, the Unaccusativity Hypothesis (Burzio, 1986; Perlmutter, 1978), accounts for the observation that subjects of UA verbs are not agents of the action, but are rather undergoing the action described by the verb (the dog is not causing anyone to disappear: the dog is, itself, vanishing). Since the role of 'undergoer' or 'theme' of the action is attributed to objects, the noun phrase receives the appropriate theta-role postverbally and then moves to the preverbal position for theory-internal reasons. More to the point of our study, the displacement leaves a trace in the object position whose antecedent is the surface subject (dog).

By contrast, the sole argument of unergative verbs (UE; *The student laughed*.) is a true subject: *the student* is actively doing the action of laughing. Consequently, the subject receives the role of agent of the action in the preverbal position and no postverbal trace is postulated with UE verbs. Interestingly, Friedmann and colleagues (Friedmann, Shapiro, Taranto, & Swinney, 2008) observed a processing difference between UA and UE verbs: postverbal priming for the subject was only obtained with UA verbs.[2] These results are in line with the predictions that the presence of the trace with UA verbs would trigger the postverbal reactivation of the trace's antecedent, the subject. Since no trace follow UE verbs, no such reactivation was expected with these predicates. In sum, UA verbs have a trace in the object position whose antecedent is the subject, whereas UE

[2] The downstream position was located 750ms after the offset of the verb. Friedmann et al. (2008) argue that the reason the effect was not observed at the offset of the verb is due to the time the processor requires to detect the trace. In effect, the trace is invisible: the anaphor is absent from the input and there are no overt cues to hint to its upcoming presence. Thus, its presence must be inferred from postverbal context, which would explain the delay observed in antecedent re-access (Visibility Hypothesis; Fodor, 1993).

verbs do not involve traces. We exploited the properties of these verbs to test how the processor treats traces in the antecedent of a verb-phrase ellipsis.

This study: Traces in Verb-Phrase Ellipsis

In the current study, we aimed to determine if both the sloppy and the strict readings are computed in VPE when the antecedent VP contains a trace. The rationale is that if traces are mentally represented as the silent counterparts of reflexives, an identical pattern of results should be observed with trace-containing antecedents in VPE constructions and we should find evidence for the computation of the strict and the sloppy readings. We thus investigated activation patterns in VPE constructions whose antecedent VP contained an unaccusative verb (with a trace) or an unergative verb (without a trace).

The predictions were identical for the sloppy and the strict reading. We predicted that neither UA nor UE verbs would show priming for their subject at a baseline position or at the elision site. The UA-UE distinction would become visible at the post-elision site, where only UA verbs would show priming. The reason the effect was not expected at the VPE is based on Friedmann et al.'s finding that the subject of UA verbs in simple, nonelliptical sentences is re-accessed downstream from the verb, a few hundred milliseconds after the point where it is licensed.

We present two experiments: Experiment 1 tested for the computation of the sloppy reading whereas Experiment 2 probed for the strict reading. To forecast our findings from both studies, we found evidence in the elliptical clause for the sloppy

reading (subject = NP2), but not for the strict reading (subject = NP1); subject activation was observed with both verb types in the elliptical clause, starting before the ellipsis. Thus, a mechanism unrelated to the VPE seems to be responsible for re-accessing NP1 in the elliptical clause. This will be discussed in depth below (or something like that).

Experiment 1: Sloppy reading (NP2)

Rationale

This Cross-Modal Priming experiment tested for evidence of the computation of the sloppy reading. As a reminder, the sloppy reading assigns the subject of the elliptical clause (henceforth, NP2) as the antecedent of the anaphor. If the sloppy reading is computed online, evidence for the reactivation of NP2 should be observed downstream from the elision site with UA verbs.

Participants

Forty-three students from San Diego State University participated in Experiment 1 for course credit[3]. All participants were monolingual native speakers of English with normal or corrected-to-normal auditory and visual acuity. Participants reported that they had not been exposed to a second language before the age of six and had no history of neurological injury or learning disorder.

[3] Only participants who showed accuracy levels above 70% on the lexical decision task and on comprehension questions were considered in data analysis. It is assumed that a poorer performance on either task is indicative of the participant's failure to attend to or understand task requirements.

Materials

Eighteen nonalternating unaccusative verbs (UA) and eighteen unergative verbs (UE) were selected based on the criteria detailed in Friedmann et al., 2008. These thirty-six verbs were placed into sentences containing a verb-phrase ellipsis (VPE) as exemplified in [6].

[6] The dog disappeared$_{UA}$ in the crowded street fair and [the child]$_{NP2}$ with the blue jumpsuit on [did too] $_{VPE}$, much to the family's dismay.

The structure of the test sentences matched the following template: an NP subject of the antecedent clause, a UA/UE verb, a prepositional phrase, a conjunction of coordination (*and*), an NP subject of the elliptical clause (NP2), a preposition phrase, a VPE of the form 'did too' and an ending phrase. Prepositional phrases always started with *in*, *with* or *from*; those in the elliptical clause were kept constant at a length that provided enough time for the decay of NP2 activation before the VPE (between 5-7 syllables). Ending phrases were included to allow for the testing of a probe position downstream from the elision site (*did too*) while circumventing end-of-sentence wrap-up effects (Balogh et al., 1998). Lastly, sentences were constructed without any internal semantic relatedness so as to avoid indirect priming effects.

In addition to the thirty-six test sentences, sixty-four fillers were generated. Twenty tokens were elliptical sentences with transitive verbs, while the remaining forty-four constructions varied in syntactic complexity and length but, importantly, were non-

elliptical. In addition to these items, twenty yes/no questions per session were composed (30% of the questions referred to test tokens). The questions were presented at irregular intervals with the goal of encouraging attention to the sentences. Finally, an additional ten sentences and two questions were created to form a practice session. In sum, thirty-six out of the hundred and thirty-two tokens that composed a session were test items.

Test sentences were associated with a pair of visual probes (fillers, with a single probe) that were English words. For test tokens, one probe was semantically related to the subject of the elliptical clause (NP2); the second probe was semantically unrelated to NP2. Related and control/unrelated probes were matched on frequency and baseline reaction times.[4] Importantly, particular attention was given to avoid any additional semantic relatedness between the prime, the probes and the remaining of the sentences, especially the verbs. For fillers (including practice), nineteen of the probes were English words (never semantically related to the filler sentences) and the remaining fifty-five probes were nonwords of English. In short, across practice items, fillers and test sentences, exactly half of the visual probes were real words of English and only 18/132 had a semantic relation to their associated sentence. Control and related probes for each test sentence are included in the Appendix.

Probe positions in fillers were randomly dispersed, preventing participants from predicting the appearance of probes. For the test sentences, probes positions were precisely determined based on structure (positions approximated below):

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[4] Probes were taken from a database built over the years in the Language Processes Laboratory (SDSU). The probes in this database have been pre-tested for baseline reaction times and semantic relatedness to their prime.

[7] The dog disappeared in the crowded street fair and [**the child**]$_{\mathbf{NP2}}$ with the blue jump①suit on [did ② too]$_{VPE}$, much to the ③ family's dismay.

Related Probe: girl Control Probe: land

Probe positions centered on the elision site: the offset of the auxiliary *did* was defined as the second probe position (PP2). A pre-elision site position (PP1) was established at least 600ms earlier than PP2 and served as a baseline in activation. The third position (PP3) was placed 750ms after PP2 based on Friedmann et al.'s findings that UA verbs reactivate their subject/object downstream from their licensing point. Overall, participants could not predict when a probe would appear in the sentence or whether it would or would not form an English word.

Design

The design was a mixed-factor 2x3x2 design with verb type (UA, UE), probe position (PP1, PP2, PP3) and probe type (related, control) as factors. The twelve conditions were counterbalanced across twelve two-session lists. Participants came in for two sessions, one week apart, and they were randomly assigned a pair of scripts: in the first session, a sentence was presented at one probe position with a probe related to NP2; in the second session, the same sentence appeared at the same position but with a control probe. Across lists, each test sentence appeared in all conditions, with the exception of

remaining within the appropriate level of the factor Verb Type (sentences appeared with either an unaccusative or an unergative verb; verb type was a between-sentence factor).

Within a session, test and filler sentences were ordered pseudo-randomly, with the condition that no more than three items with similar properties (filler or test, verb type, probe position or type, word/nonword probe) would be sequentially presented. In sum, each sentence was only heard once per session, but twice in total. Importantly, participants contributed data to all conditions albeit using different sentence/condition combinations.

Procedure

A Cross-Modal Lexical Decision paradigm was used. A native speaker of English using a normal speech rate digitally recorded the stimuli. The sentences were aurally presented (ISI = 2sec) through headphones to participants who were sitting in a soundproofed booth, facing a computer. The visual probes appeared centrally on the screen for 300ms. Participants were asked to perform two tasks: 1) to indicate as quickly and as accurately as possible whether the visual probe was a word of English, using a two-button box; 2) listen and understand each sentence and to answer a comprehension question when prompted.

A session began with the practice session. When participants felt comfortable with the tasks at hand, the experiment started. Presentation software was used to present the auditory and visual stimuli and to record participants' accuracy and reaction times (during

a 1500ms time window following the appearance of the probe) with millisecond accuracy.

Results

Prior to analysis, we discovered that one sentence (UA1) contained a pronoun in the elliptical clause that could have primed NP2, it was therefore excluded from all further analyses. Incorrect responses ("nonword" or failure to respond in the allotted time) were excluded, which represented 4.4% of the data. Data from correct responses were compiled. To limit the impact of extreme values, data points above or below three standard deviations from a participant's overall mean were replaced with the participant's overall mean (1.78% of data replaced).

Mean reaction times for each of the conditions were calculated. A priming effect was obtained when $RT_{related} < RT_{control}$ and interpreted as evidence that the prime (i.e., NP2) was activated at that point in time. Table 2.1 presents conditional means, standard deviations and priming effects (control minus related RTs). As detailed below, statistically significant priming was observed with UA verbs starting at the elision site (PP2). No similar facilitatory effect was obtained for UE verbs.

Table 2.1 Mean reaction times and standard deviations to NP2-related and control probes for each verb type and probe position. * = statistically significant.

NP2		PP1		PP2		PP3	
Verb	**Data**	**Control**	**Related**	**Control**	**Related**	**Control**	**Related**
UA	**Mean**	696	678	705	681	690	664
	(SD)	(111)	(119)	(115)	(121)	(121)	(107)
	Priming Effect	*18*		*24**		*26**	
UE	**Mean**	658	664	674	679	664	694
	(SD)	(97)	(105)	(97)	(107)	(97)	(118)
	Priming Effect	*-6*		*-5*		*-30**	

An Analysis of Variance (ANOVA) was performed with participants as the random variable and verb type, probe position and probe type as within-subject factors.[5] A main effect of verb type was found, such that UA verbs yielded slower responses than did UE verbs (685 vs. 672 ms; $F(1,42) = 7.85$, $p < 0.01$, partial $\eta^2 = 0.16$). A verb type-probe position interaction approached significance ($F(2,84) = 2.96$, $p = 0.057$; partial $\eta^2 = 0.07$), and verb type interacted with probe type ($F(1, 42) = 14.95$, $p < 0.001$; partial $\eta^2 = 0.26$), indicating that UA and UE verbs induced distinct response patterns. To clarify the relation between these factors and to test specific predictions, one-tailed t-tests were carried out separately for UA and UE verbs.

[5] We believe F2 analyses (items as a random factor) are inappropriate in this study, because the factor's levels are not a random sample taken from a larger population to which we aim to generalize. That is, our verbs –and by extension, the sentences- were not randomly sampled; they were carefully selected for their properties. In fact, we have virtually used up the pool of non-alternating unaccusative verbs for this study. We thus only report the participant-based analyses.

We first turn to UA verbs and the prediction that NP2 reactivation (that is, a priming effect) would be observed in the elliptical clause. Our predictions were mostly supported: a priming effect was obtained at PP3 ($diff_{mean}$ = 26; t_{42} = 2.77, $p < 0.01$; 95% confidence interval = [10.2-∞]), but also at the earlier PP2 ($diff_{mean}$ = 24; t_{42} = 2.05, $p < 0.05$; 95%CI = [4.37-∞]), that is, directly at their licensing, elided position. Importantly, we confirmed that no reliable priming was found at PP1 ($diff_{mean}$ =18; t_{42} = 1.05, $p > 0.05$; 95%CI = [-10.9-∞]). Thus, the priming effect obtained at PP2 was unlikely due to residual activation from processing the NP2 earlier in the sentence. Rather, the re-access of the elliptical clause's subject was more likely attributable to the presence of the VPE at PP2.[6]

By contrast with UA verbs and consistent with our expectations, no priming was found with UE verbs at the pre-ellipsis or ellipsis positions (PP1: $diff_{mean}$ = -6; t_{42} = -0.51, $p > 0.05$; 95%CI = [-26.29-∞]. PP2: $diff_{mean}$ = -5; t_{42} = -0.49, $p > 0.05$; 95%CI = [-23.59-∞]). Unexpectedly, however, NP2-related probes induced longer reaction times than their control counterparts at the downstream position (PP3: $diff_{mean}$ -30; t_{42} = -2.76, $p < 0.01$; 95%CI = [-∞ − -11.55]). This negative effect may indicate a processing cost and disadvantage to re-accessing a UE subject at this later point. Still, our results unambiguously confirm the processing contrast between UA and UE verbs.

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[6] We note that reaction times were indeed faster in the related than in the control condition. However, this difference was not statistically significant and could simply result from the not-quite-decayed activation from hearing the subject. Importantly, the [control-related] difference gained in magnitude and became statistically reliable at PP2, at the temporal location of the covert verb. Moreover, UE verbs by contrast did not show a similar priming effect at PP1, indicating that UA and UE verbs yield distinct activation patterns in the elliptical clause.

Discussion of Experiment 1

Experiment 1 tested whether trace-containing unaccusative verbs (UA) yielded the computation of a sloppy reading in verb-phrase ellipsis (VPE). Reactivation of the elliptical clause subject (NP2) was expected with UA and not UE verbs. For UA verbs, NP2 re-activation was observed starting at the elision site. By contrast, no such effect was obtained with unergative verbs (UE) at the VPE. These findings confirm that UA and UE verbs are processed differently and are consistent with the hypothesis that a covert anaphor is present postverbally in UA verbs. We begin our discussion with a closer look at the results regarding UA verbs.

We note that the onset of NP2 activation was earlier than expected (PP2 vs. PP3). NP-traces, such as those involved in UA verbs, have been shown to re-access their antecedents at a point in time later than their stipulated licensing position (Friedmann et al., 2008; Osterhout & Swinney, 1993). This delayed effect has been attributed to the absence of early, overt cues hinting to the upcoming presence of the covert anaphor (Fodor, 1993). Because the anaphor cannot be predicted in advance, the processor must infer its existence and location from context–typically after the anaphor is 'passed'. Thus, an antecedent is assigned to an NP-trace once the anaphor is detected, later than its actual position. Consequently, in the current study, it was expected that NP2 would be reactivated at the downstream position (PP3), where the processor may have obtained

enough information to infer the existence of the trace.[7] Although NP2 was indeed activated at PP3, its reactivation began at PP2. This pattern perfectly parallels that of reflexives, whose antecedent is re-accessed at the elision site.

Why would a UA subject be re-accessed earlier in VPE compared to simple sentences? One possible explanation stems from a difference in structure between VPE and simple sentences: simple sentences are composed of one clause, whereas VPE constructions involve two clauses. It may be the case that the first clause in VPE had a sentential priming effect on the second clause: the parser may have assumed that the structure of the elliptical clause would resemble that of the antecedent-containing clause. In doing so, the parser may have postulated a trace postverbally, as in the antecedent clause, before the context in the elliptical clause could confirm its presence.

Such sentential or syntactic priming is a well-known phenomenon (see Pickering & Ferreira, 2008 for an extensive review). It has repeatedly been demonstrated that processing a syntactic structure is easier and faster when it follows a similar structure. Moreover, a syntactic structure can prime the parser to favor one of two possible parses in syntactically ambiguous sentences, suggesting that the second clause may be processed to reflect the structure of the first clause. Sentential priming is not limited to syntactic

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[7] Friedmann and colleagues (2008) report subject reactivation with nonalternating UA verbs downstream from the verb. The authors attributed the late effect to the fact that there are no overt cues of the upcoming trace; thus, it must be inferred from postverbal context. However, it is unclear why the parser would need context to infer the existence of a trace with non-alternating unaccusatives such as those used in this study. These verbs were precisely selected for their unaccusativity property and for their lack of alternative interpretations. That is, nonalternating unaccusatives can never appear with subjects that are agents of the action (like UE verbs) or with an overt object (like transitive verbs–*eat an apple*): these verbs always appear with an object-turned-subject. Since argument structure is available immediately at the offset of a verb (Shapiro, Zurif, & Grimshaw, 1987), the information that nonalternating UA verbs must appear with a covert object/trace is available at the offset of the verb and could be used to infer the presence of the trace earlier. Hence, the presence of NP2 at the VPE may not be so surprising considering the fact that the trace can technically speaking be inferred this early via the verb's argument structure.

structure: the repetition of lexical items magnifies the facilitation effect. Hence, it may be the case that the parser, when facing a second clause, refers to the first clause to facilitate the processing of the second. With respect to the current study, the parser would have expected the same structure to arise in the elliptical clause and surmised the presence of a trace at the same position where one was found in the first clause. Indeed, parallelism effects have been claimed to facilitate or guide processing (Apel, Knoferle, & Crocker, 2007; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Callahan, Shapiro, & Love, submitted; Knoeferle, 2007; Knoeferle & Crocker, in press). Alternatively, it may not have been necessary to postulate the trace it the second clause since the covert anaphor was included in the first-clause VP. Consequently, the verb and its (covert) object would have been reconstructed immediately when the antecedent verb phrase was re-accessed at the VPE (just like overt objects are re-activated at the elision site). In other words, the presence of the verb in the first clause would have facilitated the processing of the verbal trace in the second clause. It thus seems that sentential priming or parallelism accelerated the detection of the covert anaphor in the VPE (see also discussion of Experiment 2). Crucially, however, the exact timing of the priming effect does not call into question the unambiguous conclusion that NP2 was re-activated by the VPE.

The activation patterns observed with UA verbs can confidently be attributed to the verbs' properties, since distinct patterns were found for UE verbs. In effect, the differential results between UA and UE verbs rule out the possibility that, for some reason, subjects of all intransitive (i.e., one-argument) verbs are reactivated. Furthermore, the properties of UE verbs straightforwardly account for the absence of an NP2

facilitation effect at the VPE: considering UE verbs do not have postverbal traces, no re-activation of their subject was expected. Our findings replicate those of Shapiro and colleagues (2003) and confirm that not all verbal subjects are reactivated at the elision site in VPE.

Moving on to UE verbs, the subject was not activated at the elision site: no priming effect was observed at PP2. This result further supports the claim that attributing meaning to VPE does not involve verbal subjects unless the antecedent contains a reflexive or trace (Shapiro et al., 2003). In other words, VPE is interpreted similarly to other anaphora: by re-accessing its syntactically-licensed antecedent (the VP) as soon as the anaphor is processed. However, UE verbs did yield a reliable difference between subject-related and unrelated probes at the downstream position. Furthermore, this effect was not one of facilitation: decisions on subject-related probes were *slower* than on unrelated probes.

Such "negative effects" are difficult to interpret but could be attributable to subject-specific inhibition or processing difficulty. For instance, the increased RTs to subject-related probes suggest that the presence of a UE subject in the postverbal position was detrimental to the interpretive process. The processing cost with UE verbs may pertain to the central role verbs play in theta-role assignment. As explained in the introduction, verbs rely on the linear order of their arguments to determine who did what to whom. For example, an argument in the postverbal position will receive the role of 'undergoer' of the action, whereas an argument in the preverbal position will be assigned the role of agent of the action. Theoretically, the postverbal re-activation of a UA subject

is driven by the need for an 'undergoer' role; by contrast, a UE subject has already received its appropriate role preverbally. Consequently, its presence in a postverbal position may create interference if the processor attempts to assign it an additional (and incorrect) thematic role. Importantly, the cost would be seen only with UE verbs and only if the subject is claimed to be activated postverbally. Clearly, further research is needed to elucidate the interplay of thematic role assignment, argument activation and covert anaphora.

To summarize, Experiment 1 examined whether UA verbs in VPE yielded the computation of the sloppy reading (NP2 reactivation). Priming for the subject of trace-containing UA verbs was obtained at the elision site, contrary to UE verbs. These results are directly in line with the literature on anaphora, which consistently reports that only the legal antecedent of the anaphor is re-accessed. These findings indicate that the sloppy reading was computed with UA verbs and are consistent with the view that traces are represented as silent reflexives, but also with the Direct Association Hypothesis. The patterns of NP1 activation (Experiment 2) are expected to tease the two approaches apart.

Experiment 2: Strict Reading (NP1)

Rationale

This Cross-Modal Priming experiment tested for evidence of the computation of the strict reading. The strict reading assigns the subject of the antecedent clause

(henceforth, NP1) as the antecedent of the anaphor. If the strict reading is computed online, evidence for the reactivation of NP1 should be observed downstream from the elision site with UA verbs.

Participants

Forty-five students from San Diego State University who had not been involved with Experiment 1 participated in Experiment 2 for course credit[8]. All participants were monolingual native speakers of English with normal or corrected-to-normal auditory and visual acuity. Participants reported that they had not been exposed to a second language before the age of six and had no history of neurological injury or learning disorder.

Materials, Design, Procedure

The same stimuli as Experiment 1 were used, with the exception of test probes that were now associated with the subject of the antecedent clause, NP1:

[8] **[The dog]$_{NP1}$** disappeared in the crowded street fair and the child with the blue jump①suit on [did ② too]$_{VPE}$, much to the ③ family's dismay.

Related Probe: cat Control Probe: land

[8] As in Experiment 1, only participants who showed accuracy levels above 70% on the lexical decision task and on comprehension questions were considered in data analysis. It is assumed that a poorer performance on either task is indicative of the participant's failure to attend or understand the experimental paradigm.

Consequently, their associated control probes were also changed so as to match the related probes in baseline reaction time and frequency. Control and related probes for each test sentence are included in the Appendix. Everything else was identical to Experiment 1.

Results

One sentence (UA2) was excluded from analysis because it contained a related noun phrase ("suburban") in the elliptical clause that could have primed NP1 ("trucker"). Incorrect responses ("nonword" or failure to respond in the allotted time) were excluded, which represented 2.7% of the data. Data from correct responses were compiled. To limit the impact of extreme values, reaction times (RTs) above or below three standard deviations from a participant's overall mean were replaced with the participant's overall mean (1.5% of data replaced).

A priming effect was obtained when $RT_{related} < RT_{control}$ and was interpreted as indicating that the prime (i.e., NP1) is activated at that point in time. Table 2.2 presents conditional means, standard deviations and priming effects (control minus related RTs). To foretell the findings, significant priming effects were observed beginning at the earliest position (PP1) for both verb types.

Table 2.2 Mean reaction times and standard deviations to NP1-related and control probes for each verb type and probe position. * = statistically significant.

NP1		PP1		PP2		PP3	
Verb	**Data**	**Control**	**Related**	**Control**	**Related**	**Control**	**Related**
UA	**Mean**	725	702	728	700	704	688
	(SD)	(124)	(119)	(147)	(129)	(124)	(118)
	Priming Effect	*23**		*28**		*16*	
UE	**Mean**	718	698	721	698	701	690
	(SD)	(129)	(140)	(142)	(156)	(133)	(117)
	Priming Effect	*20**		*23**		*11*	

An analysis of variance was performed with participants as the random variable and with verb type (UA, UE), probe position (PP1, PP2, PP3) and probe type (control, related) as within-subject factors.[9] Main effects of probe position ($F(2,88) = 4.02$, $p < 0.05$; partial $\eta^2 = 0.08$) and probe type ($F(1,44) = 15.90$, $p < 0.001$; partial $\eta^2 = 0.26$) were obtained, indicating that probes were responded to differentially between positions and depending on semantic relatedness.

We proceeded to test our hypotheses with *a priori* one-tailed paired t-tests. The priming patterns observed for UA verbs were not what had been predicted: facilitation effects were observed at both earlier positions (although marginally at PP1: $diff_{mean} = 23$; $t_{44} = 1.58$, $p = 0.06$; 95%CI = [-1.42-∞]. PP2: $diff_{mean} = 28$; $t_{44} = 2.23$, $p < 0.05$; 95%CI = [-7.01-∞]), and had lost statistical significance by PP3, where priming was expected

[9] See Experiment 1 for the justification of a participant-based only set of analyses.

($diff_{mean}$ =16; t_{44} = 1.37, p = 0.09; 95%CI = [-3.49-∞]). Surprisingly, the same pattern of effects was observed with UE verbs: contrary to our predictions, significant priming effects were found at the pre-elision and elision positions (PP1: $diff_{mean}$ =20; t_{44} = 1.93, p < 0.05; 95%CI = [2.56-∞]. PP2: $diff_{mean}$ = 23, t_{44} = 2.11, p < 0.05; 95%CI = [4.72-∞]). As with UA verbs, the facilitation effect was no longer statistically reliable at PP3 ($diff_{mean}$ =11; t_{44} = 1.24, p = 0.11; 95%CI = [-3.94-∞]).

Discussion of Experiment 2

Experiment 2 tested whether the strict interpretation (NP1 reactivation with UA verbs) was computed online. We probed for the subject of the antecedent clause in the elliptical clause. We observed strikingly similar patterns with UA and UE verbs: both verb types yielded NP1 priming at the pre-ellipsis and ellipsis positions.

To begin with, we did obtain reliable priming at the elision site with UA verbs but the presence of a significant effect at the baseline position prevents the conclusion that NP1 was *re*-activated at PP2. Since no significant decay in activation was detected prior to PP2, it seems to be the case that NP1 was activated at an earlier point in the sentence and maintained activated until the elision site.[10] Interestingly, the same pattern of results is observed with UE verbs. These mirror effects between UA and UE verbs reinforce the claim that these activations are unrelated to the VPE or to verb-specific properties.

[10] This conclusion is further supported by the fact that the duration of the segment between PP1 and PP2 was about 600ms, which is at least twice as long as needed for a priming effect to decay − even in older individuals (e.g. Love, Swinney, Walenski, & Zurif, 2007; Nicol & Swinney, 1989).

So what may be driving NP1 activation in the elliptical clause? We can begin by ruling out several potential methodological confounds. One, there is no anaphor in the segment between the conjunction '*and'* and the VPE. So the early priming effects cannot be due to accidental antecedent reactivation. Our stimuli were also well controlled so that no semantic relatedness could be found within a sentence.[11] As a result, no lexical item in the pre-VPE segment could cause indirect priming. In addition, the statistical reliability and the magnitude of the priming effects rule out any item-specific confound such as the presence of a related lexical item. Consequently, the priming effects are probably meaningful and indicative of a mechanism operating before the ellipsis is processed.

This mechanism, we suggest, is related to the processing of coordinated structures and the expectation of parallelism. All of our UA and UE sentences were formed of two clauses joined by the conjunction of coordination 'and'. Coordination has been reported to induce a parallelism effect such that the second conjunct is processed more quickly than the first conjunct if they share similar structure, semantic content, or both (Frazier et al., 1984, 2000; Apel et al., 2006; Knoeferle, 2007; Knoeferle & Crocker, in press; inter alia). The expectation of parallelism seems to come from processing the conjunction of coordination. In effect, when a non-contrastive conjunction is used (e.g.,"but", "because"), parallelism effects are eliminated (Knoeferle, 2007). Thus, processing the conjunction "and" induces an expectation of parallelism in the second conjunct. This expectation seems to elicit reference to the first conjunct, whereby first-

[11] In fact, we excluded two experimental items because of such potential confounds (Experiment 1, token UA1: presence of a pronoun, *his*; Experiment 2, token UA2: semantic relatedness of *suburban* to NP1's *truck driver*).

conjunct material would be re-activated immediately after the conjunction is processed (see Callahan et al.., submitted, for evidence of verb reactivation; the current study for evidence of subject reactivation[12]; Shapiro et al.., 2003 for evidence of object reactivation; Knoeferle, 2007 for evidence of early facilitation effects). Activation of the first-conjunct material may guide parsing and be sustained until the second conjunct is processed.[13] In the case of parallel conjuncts, this strategy pays off and results in facilitated processing.[14] Our findings also suggest that parallelism effects are required for the early detection of an ellipsis. In effect, ellipsis resolution is observed earlier (at the temporal position of the covert anaphor) in constructions that induce an expectation of parallelism (i.e., 'and'-coordinated sentences) than in constructions where no parallelism is expected ('but'- and 'because'-joined sentences) (Shapiro & Hestvik, 1995; Kaan et

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[12] Unlike what we have observed here, Shapiro and colleagues (2003, Experiment 3) did not observe priming for the subject at their pre-elision site. We note that Shapiro et al. used transitive verbs and thus, in principle, there may have been an expectation of a complex NP (underlined) formed from the object in the antecedent clause and the subject in the elided clause (*The army general criticized the food, and the congressman, who was [PP1] his best friend, did [PP2] too, according to other high-ranking officers*). The processor would then not reactivate the entire clause, expecting for it not to be implicated in the conjunction.

[13] Carlson (Carlson, 2001) studied the effect of parallelism on the processing of sentences such as "Josh visited Marjorie during the vacation and Sarah during the week", where the interpretation is ambiguous between "Josh visited Marjorie and Sarah" and "Josh and Sarah visited Marjorie". Parallelism between conjuncts significantly induced a higher ratio of gapping interpretation, suggesting that parallelism can influence parsing.

[14] The expectation of parallelism in coordinated constructions may facilitate the detection of elided material by predicting its upcoming occurrence based on the structure of the first conjunct. In effect, the missing verb in gapping constructions (*John loves pie and Mary, brownies*) is reported to be detected virtually immediately (within 100-300ms of its location; Kaan, Wijnen, & Swaab, 2004). Interestingly, the materials used by Kaan and colleagues were perfectly parallel coordinated sentences. It would be interesting to see if the gapped verb is detected as quickly in the absence of parallelism. One cue might come from a study of coordinated and subordinated VPE constructions (*John left the party and/because Mary did too)* (Shapiro & Hestvik, 1995). The VPE was detected and its antecedent retrieved immediately in the coordinated sentences. In the absence of the expectation of parallelism (in the subordinated constructions), the antecedent was activated some 600ms later. The delay in interpreting the VPE may be attributable to the necessity to establish a causal relation between the first clause and the second (the reason John left is that Mary did), or may related to the late detection of the ellipsis when no syntactic structure in particular is expected.

al., 2004; Poirier, Shapiro, Wolfinger and Spellman, in preparation). Whether or not the early priming effects are related to an expectation of parallelism, the activation of NP1 at a position preceding the elision site and the mirror effect between UA and UE verbs strongly support the conclusion that the priming effects are not attributable to the VPE or to the UA trace.

To sum up, it is unlikely that the strict reading was computed in this experiment. In effect, we did not observe clear re-activation of the subject of the antecedent clause, NP1, with UA verbs: we could not confirm that priming had decayed prior to the VPE. Although no strong conclusion can be drawn, the observed activations seemed to be induced by a mechanism that applies early in the sentence. We suggested that this mechanism is related to an expectation of parallelism due to the presence of the conjunction '*and'*.

General Discussion

In this study, we aimed to determine whether traces are represented as silent reflexives. If so, we hypothesized, similar processing behavior should be observed with traces and reflexives. We elected to target the online processing of trace-containing unaccusative verbs (UA) in Verb-Phrase Ellipsis (VPE) as a basis for comparison. Assuming traces are mentally represented as reflexives, we expected to observe the computation of the sloppy reading (NP2 reactivation) and of the strict reading (NP1 reactivation). In Experiment 1, we found evidence that NP2 is re-activated with UA verbs

at the VPE where the trace is postulated. Experiment 2 could not confirm or refute whether a strict reading is computed with UA verbs. Hence, these results on the representational status of traces are consistent with trace-based and traceless accounts of language processing. Interestingly, however, Experiment 2 offers novel evidence of a role of parallelism expectation in online processing and suggestively extends this role to the detection of covert material.

Processing VPE

Although this study utilized VPE as a research tool and did not aim to investigate the processing of VPE *per se*, a few conclusions can be drawn from our results. First, our NP2 results clearly confirm that the unaccusative/unergative verbs distinction is relevant to the parser, which recognizes and uses this lexical information immediately at the VPE. It is interesting to note that other verb properties have been studied in VPE and were reported not to influence the initial parse of the sentence (Shapiro et al., 2003): for instance, verbs of inalienable possession (*to wink one's eye*) did not prevent the computation of the strict reading, although it is an illegal interpretation of the VPE ('*the policeman winked his eye and the fireman did too'* cannot be understood as the fireman winking the policeman's eye). In the case of unaccusativity/unergativity, however, the verbal property was immediately considered and resulted in processing differences between UA and UE verbs. These results suggest that the parser can differentiate verbal properties. One interesting question would seem to be: Just exactly what properties count when computing on-line structure? Further work may be able to answer such a question.

Second, our NP2 results replicate the finding that the syntactically-defined antecedent of the VPE, the first clause VP, is retrieved and integrated into the elliptical clause as soon as the ellipsis is licensed. Relatedly, not all arguments of the verb are indifferentially re-activated. For instance, neither the antecedent-clause subject (NP1) nor the elliptical clause subject (NP2) were activated at the VPE with the antecedent VP automatically re-accessed (as Koeneman, Bauuw, & Wijnen, 1998 have claimed), nor is the subject of the elided verb (NP2-UE verbs). In effect, subjects of the verb are only re-activated at the elision site when linked to an anaphor in the object position, such as a reflexive or a trace (see also Shapiro & Hestvik, 1995; Shapiro et al., 2003).

However, it may very well be the case that once the antecedent to the ellipsis is retrieved, its full integration into the sentential context requires a re-evaluation of the verb's relations to its arguments. This hypothesis is supported by the observation of argument (object and subject) activations and of increased processing loads in the post-VPE segment (Kaan et al.., 2004; Martin & McElree, 2007). At the very least, this study confirms that a link to the antecedent VP is established at the elision site to attribute meaning to VPE and that not all arguments of the verb are involved in this process.

(NP)-traces

Our study replicates the finding that unergative and unaccusative verbs are processed differently (Friedmann et al.., 2008). According to the Unaccusativity Hypothesis, the distinction between UA and UE verbs lies in the presence of a trace postverbally with the former group of verbs. This hypothesis is supported by the

observation of the computation of the sloppy reading, or the re-activation of NP2, with UA verbs only. However, the activation patterns observed with NP1 preclude any conclusion about the strict reading because the observed parallelism-related NP1 activation may conceal trace-induced NP1 re-activation. Teasing apart the two potential sources of subject activation would require the elimination of the expectation of parallelism, which would effectively remove the obscuring early and sustained activation. Activation of NP1 in the elliptical clause of such sentences, then, would be indicative that UA verbs also yield a strict reading.

The aim of this study was to determine whether traces are mentally represented as lexical items, that is, as phonetically unrealized reflexives. If so, we hypothesized, traces such as those associated with UA verbs would be processed similarly to their overt equivalent, reflexives (*himself*). We found partial support for this hypothesis: UA traces re-activate their local antecedent (NP2) in VPE as reflexives do. However, it could not be confirmed that traces also re-access their non-local antecedent (NP1). Our results are thus consistent with trace-based and trace-less processing accounts. Nonetheless, our results elucidate the role of subjects in the interpretation of VPE. We demonstrated that certain verb properties are immediately taken into consideration by the parser and replicated the finding that only the antecedent VP is re-accessed at the elision site—not all verbal arguments. Further, we suggested that verbal arguments may be re-activated *downstream* from the covert verb to build an integrated representation of the elliptical clause. The current study offers additional evidence that parallelism expectation results in the reactivation of first-conjunct material in the second conjunct. Interestingly, our findings

also hint to an important role of parallelism on the detection and comprehension of anaphora that warrants further research.

Appendix

UA1 The teller arose in an angry state, and the magician with a spoon in his hand did too, while the horrible singer kept singing.

NP1	C	wood	NP2	C	bunch
	R	bank		R	trick

UA2 The trucker arrived in Montana and the DEA agent in the red suburban did too, while the village was celebrating its centennial.

NP1	C	lotion	NP2	C	date
	R	diesel		R	drug

UA3 The grandmother departed with six large brown bags and the gardener in dirty clothes from work did too according to the store clerk.

NP1	C	politics	NP2	C	blood
	R	relative		R	plant

UA4 The surgeon descended from the top of the stairs and the senator with a suit and tie on did too, around the time dinner was being served.

NP1	C	drain	NP2	C	programs
	R	knife		R	congress

UA5 The dog disappeared in the crowded street fair and the child with the blue jumpsuit on did too, much to the family's dismay.

NP1	C	bus	NP2	C	land
	R	cat		R	girl

UA6 The nun dwelt in the school library, and the plumber in the magenta pants, did too as the football game was coming to an end.

NP1	C	bull	NP2	C	coins
	R	monk		R	pipes

UA7 The Martian emerged from inside the trailer and the acrobat from Philadelphia did too as it was time to do the scene.

NP1	C	helium	NP2	C	stewardess
	R	galaxy		R	somersault

UA8 The cook existed in a stressed state of mind, and the lieutenant from Trenton, New Jersey, did too, after the wedding ceremony was over.

NP1	C	list	NP2	C	data
	R	food		R	army

UA9 The manicurist fell from the rollercoaster, and the movie star with a loud high-pitched scream, did too, according to the newspaper reporter.

NP1	C	smog	NP2	C	vegetable
	R	nail		R	celebrity

UA10 The memo appeared in the blink of an eye, and the monkey with the colorful hat did too, according to the humorous article.

NP1	C	lake	NP2	C	botany
	R	page		R	banana

UA11 The mailman persisted with a determined look, and the drunk with a staggering walk did too, according to the delivery man.

NP1	C	steer	NP2	C	decorator
	R	stamp		R	alcoholic

UA12 The lawyer remained in the dance club, and the dentist from Atlantic City, did too, while it was snowing outside.

NP1	C	table	NP2	C	moon
	R	trail		R	teeth

UA13 The bartender rose from the parade float and the bride with the bad haircut did too, while the crowd watched and waved.

NP1	C	tribute	NP2	C	rash
	R	whiskey		R	veil

UA14 The spy smoldered from a well-hidden spot, and the comedian with a limp and a cane did too, while the dog ran past.

NP1	C	knit	NP2	C	patience
	R	code		R	laughter

UA15 The king surged from behind the couch, and the coach in the black tuxedo, did too, while the band kept playing.

NP1	C	split	NP2	C	bear
	R	queen		R	team

UA16 The cardiologist thrived in the tropical sun, and the athlete in the purple jump suit did too, while the plane flew past in the distance.

NP1	C	mouth	NP2	C	screen
	R	heart		R	sports

UA17 The caddie towered from a great distance, and the banker from Boise, Idaho, did too, according to the photograph.

NP1	C	razor	NP2	C	music
	R	golf		R	money

UA18 The parakeet vanished from the fourth grade classroom and the tiger with the lame right hind paw, did too, while the security guard slept.

NP1	C	nickel	NP2	C	priest
	R	parrot		R	lion

UE1 The spider crawled into the windowsill and the boy from the second grade class did too after the smoke began to fill the room.

NP1	C	hut	NP2	C	clear
	R	web		R	child

UE2 The roofer cried from the side of the road, and the jeweler, from the desk in the store, did too, after the best hardware shop in town was closed down by the government.

NP1	C	beef	NP2	C	log
	R	roof		R	gem

UE3 The chauffeur danced with enthusiasm and the librarian, in awe of the winners, did too on the opening night of the tour.

NP1	C	wisdom	NP2	C	edge
	R	driver		R	book

UE4 The florist jumped from the red, comfy couch and the barber from Los Angeles did too, while the waiter was snoring next door.

NP1	C	thumb	NP2	C	ramp
	R	bloom		R	comb

UE5 The people laughed at the animals, and the guards from across the city did too, according to all the children.

NP1	C	purse	NP2	C	sun
	R	crowd		R	gun

UE6 The deejay lied with a broad toothy smile, and the prince with the blonde curly hair, did too, according to the official report.

NP1	C	union	NP2	C	goat
	R	radio		R	duke

UE7 The skier raced from the mountain top and the pupil from the old neighborhood did too while it was pouring cats and dogs.

NP1	C	safe	NP2	C	freedom
	R	snow		R	student

UE8 The clown retired from the starting project, and the nanny from Miami, Florida, did too, after the winning lottery ticket was announced.

NP1	C	cradle	NP2	C	horizon
	R	circus		R	nursery

UE9 The landlord screamed from inside the car wash and the priest with a black pen in hand did too as the newly signed agreement flew away in the light evening breeze.

NP1	C	pond	NP2	C	square
	R	rent		R	church

UE10 The postman sang to the whole family, and the astronaut in the red two-piece suit, did too, during the holiday celebration.

NP1	C	core	NP2	C	floor
	R	mail		R	space

UE11 The golfer sat in the huge armchair and the wife with a bowl of popcorn did too as the made-for-t.v. movie began.

NP1	C	neck	NP2	C	police
	R	club		R	husband

UE12 The professor slept in the upstairs guest room, and the marine in town for two short days, did too, after the fast-paced scrabble tournament ended in the den.

NP1	C	problems	NP2	C	text
	R	students		R	ship

UE13 The sailor smiled in amusement and the cameraman in the front of the crowd did too as the minister bumped into a distinguished lady with purple hair.

NP1	C	rain	NP2	C	carpet
	R	boat		R	camera

UE14 The instructor stumbled from the top of the platform, and the mother with the costly Coach purse, did too, according to the video footage.

NP1	C	traffic	NP2	C	forces
	R	teacher		R	father

UE15 The ranger talked with the pretty woman and the painter from Southern Ohio did too, after everyone else had left.

NP1	C	prison	NP2	C	cement
	R	forest		R	canvas

UE16 The chiropractor trembled in the large living room, and the shortstop from Philadelphia, did too while the mechanic reached into his pocket.

NP1	C	door	NP2	C	cupboard
	R	back		R	baseball

UE17 The fisherman waved from across the room and the cowboy with a wedding ring on did too when a gorgeous woman in a floral dress entered.

NP1	C	scout	NP2	C	bottom
	R	trout		R	cattle

UE18 The musician winked at the cute bartender, and the tourist, with a carefree smile, did too, while people were entering the club.

NP1	C	ratio	NP2	C	forgiven
	R	piano		R	vacation

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CHAPTER 3

The Real-Time Processing of Sluiced Sentences

Abstract

Ellipsis refers to an element that is absent from the input but whose meaning can nonetheless be recovered from context. For instance, in *Mary visited Tokyo last year and Jenny did too*, comprehenders readily understand that Jenny visited Tokyo last year as well. These sentences demonstrate that the parser can lean on earlier, overt parts of the sentence (the *antecedent* of the ellipsis) to interpret the elided material. The relation between the ellipsis and its antecedent is established in real time, as soon as the ellipsis is detected, and results in the antecedent getting re-activated in the elliptical clause. In this cross-modal priming study, we examined the online processing of Sluicing, an ellipsis whose antecedent is an entire clause: *The handyman threw a book to the programmer but I don't know which book [the handyman threw to the programmer]*$_{ellipsis}$. We aimed to determine the point in time at which the sluiced sentence is detected and whether such a complex antecedent is re-accessed by the ellipsis. Out of the two antecedent constituents probed for, only the Object (*programmer*) was found in the elliptical clause, confirming that an antecedent is attributed to the sluice in real time. Possible reasons for the non-observation of the Subject (*handyman*) are considered. Lastly, these results further support the hypothesis that ellipses are detected earlier in coordinated than subordinated sentences.

The term Ellipsis refers to a widely common family of constructions in which a part is unpronounced. For example, in sentence [1], no verb is present in the second clause (the ellipsis is represented by Ø), yet comprehenders readily understand that Luis likes brownies:

[1] Jillian likes apple pie and Luis, Ø brownies.

To understand an elliptical sentence, the content of the elided or silent material must be recovered from an earlier part of the sentence, the *antecedent* (underlined in [1]). Ellipsis is subject to a Parallelism constraint that forces the elliptical clause (EC) to parallel the antecedent clause (AC). This constraint ensures that the elided material is correctly reconstructed as the verb 'likes' in [1], and not 'hate', for example. The exact nature of the parallelism requirement (semantic, syntactic or discourse-based) extends beyond the scope of this paper. For now, it suffices to note the intimate relation between the EC and AC.

The listener's ability to readily and unambiguously understand ellipsis is nothing short of remarkable: the input incompletely represents the message to convey. The burden is thus put on the listener to somehow detect the 'missing' pieces and reconstruct the intended meaning in a matter of milliseconds. Thus the comprehension system must recover the unpronounced message by finding and retrieving an antecedent that is long gone in the temporal stream by the time the ellipsis is processed. How and when the

antecedent is identified, retrieved and integrated into the sentential context are some of the questions psycholinguists are attempting to answer.

Psycholinguistics of Ellipsis

Psycholinguistic research has aimed to unveil the mechanism by which meaning is assigned to an ellipsis. In an early proposal, Frazier and Clifton (2000) suggested that an antecedent is copied into the elliptical clause, whereby the semantic content and syntactic structure of the antecedent are assigned to the ellipsis. The operation would induce higher processing costs for more complex antecedents, as more structure needs to be copied. However, several studies have reported that the complexity of the antecedent does not affect ellipsis processing (Frazier & Clifton, 2001, 2000; Martin & McElree, 2008).[1] Based on this observation, Martin and McElree argued that ellipsis does not involve syntactic reconstruction but rather a content-addressable pointer mechanism that directs the processor to the mnemonic representation of the antecedent. As a response to the absence of complexity effects, Frazier and Clifton (2001, 2005) have proposed two potential mechanisms to resolve the ellipsis: a cost-free copy operation (i.e., building structure is computationally free or cheap) and a structure-sharing process (i.e., the ellipsis and antecedent share a syntactic representation). Importantly, syntactic structure is assumed to be present at the elision site under these proposals (see Frazier & Clifton, 2005 for arguments in support of this assumption).

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[1] With one potential exception: a higher number of discourse referents (overt noun phrases) in the antecedent may decrease accuracy levels.

Once an ellipsis is detected, its antecedent is identified, retrieved from memory and integrated into the elliptical clause (EC). The processor does not wait until the end of the sentence to resolve the ellipsis; it establishes the antecedent-ellipsis link as the sentence unfolds. Support for the immediacy of establishing the link comes from a cross-modal priming study that demonstrated that the elided material is recovered in real time at the elision site (Poirier & Shapiro, submitted; Shapiro & Hestvik, 1995; Shapiro, Hestvik, Lesan, & Garcia, 2003). That is, priming – an index of lexical activation – was obtained for *tie* at the *did too:*

[4] The mailman [bought a tie]$_{VP}$ and the fireman did Ø too according to the salesclerk.

Because no priming was observed shortly beforehand, it was concluded that processing the ellipsis triggered the *re*-activation of the antecedent. In contrast, the antecedent clause's subject (*mailman*) was not re-accessed in the EC, indicating that only the syntactically-defined antecedent of the ellipsis (a verb phrase in [4]) is recovered at the elision site (Shapiro, Hestvik, Lesan, & Garcia, 2003; Poirier & Shapiro, submitted). In other words, because the VP does not include the subject, *mailman* is not observed at the elision site. This evidence is irreconcilable with the claim that antecedent-external elements are also re-accessed during the reconstruction of the elided material (Koeneman, Bauuw, & Wijnen, 1998). On the other hand, this pattern is directly in line with the literature on anaphoric relations, in which an element seeks an antecedent (e.g., a

pronoun). In these relations, the referent-seeking element triggers the immediate reactivation of the antecedent; in cases where multiple options are available, only the syntactically legal antecedent is re-accessed (Nicol, 1988). Together, these findings indicate that syntactic constraints aid the processor to connect two nonadjacent co-referents by guiding the selection and retrieval of the appropriate antecedent.

If restrictions prevent the inclusion of extraneous phrases in the reconstruction of the elided material, it is unknown whether all components within the lawful antecedent are recovered. In effect, previous studies have only investigated the re-activation of smaller antecedents (noun phrases in anaphora, verb phrase in verb-phrase ellipsis). In some cases, however, the material to recover is much more complex: for instance, Sluicing – the elliptical structure this study examined – involves the elision of an entire clause (IP):

[5a] The fifth-grader doesn't like snakes but his mother doesn't know why Ø.

[5b] The fifth-grader doesn't like snakes but his mother doesn't know why ~~the fifth-grader doesn't like snakes.~~

To comprehend [5a], the sluiced sentence (strikethrough in [5b]) must be recovered. To do so, an entire clause needs to be re-accessed from memory.

On the other hand, the antecedent in Sluicing shows variability that can be exploited to examine the mechanisms underlying ellipsis resolution; the phrases composing the antecedent clause (IP) can have many properties. For example:

[6a] [The secretary typed something]$_{IP}$, but I don't know what Ø exactly.

[6b] [The secretary typed somewhere]$_{IP}$, but I don't know where Ø exactly.

[Examples from Dickey & Bunger, under review]

In these examples, the sluiced sentence needs to be recovered from the previous clause (IP). Despite the fact that both antecedents are IPs, they differ in one aspect, the syntactic function of the postverbal Noun Phrase (*something* vs. *somewhere*). In [6a], the NP is an argument of the verb, whereas the NP is an adjunct in [6b] (only arguments are required for grammaticality – adjuncts are superfluous information). This distinction has processing consequences: Dickey and Bunger (under review) found that the elliptical clause is read more slowly in [6b]. Furthermore, they observed similar processing costs in the non-elided versions of these sentences, suggesting that the same operation apply to both types of sentences. This finding suggests that the sluiced sentence is reconstructed with a syntactic structure similar to its non-elided version.

Similarly, the mechanism underlying the reconstruction of sluiced sentences whose antecedent is incomplete can be investigated. Consider:

[7a] [The secretary typed something]$_{IP}$, but I don't know what Ø exactly.

[7b] [The secretary typed quickly]$_{IP}$, but I don't know what Ø exactly.

[Examples from Dickey & Bunger, under review]

The sluiced sentence in [7a] is reconstructed where *something* and *what* co-refer to the object typed. In contrast, in [7b], the processor is faced with a constituent of the sluiced sentence (*what*) that has no explicit counterpart in the antecedent. The 'incompleteness' of the antecedent phrase results in longer processing times in [7b] than in [7a] (Dickey & Bunger, under review; Frazier & Clifton, 1998). This processing cost seems to stem from a general penalty for non-parallelism between clauses and not from an ellipsis-specific operation to create the missing syntactic position for *what* in the sluiced sentence (Chung, Ladusaw, & McCloskey, 1995; Dickey & Bunger, under review). The notion of preference for parallel constructions will be taken up in the Conclusion.

Finally, focus is one more aspect of the antecedent that has been shown to affect ellipsis interpretation. Focus attributes syntactic and/or prosodic prominence to words of phrases. In Sluicing specifically, focus has been argued to favor an interpretation in ambiguous contexts. Consider:

[8a] [Somebody claimed that the president fired someone]$_{IP}$, but nobody knows who Ø.

[8b] [Somebody claimed that the president fired Fred]$_{IP}$, but nobody knows who Ø.

[Examples from Frazier & Clifton, 1998]

Sentence [8a] can have two interpretations: that "nobody knows who claimed that the president fired someone", or that "nobody knows who the president fired". In sentence [8b], only the first reading is possible. Yet, Frazier & Clifton (1998) report that the ambiguous sentence in [8a] was read faster than [8b], despite the potential for additional

processing involved to resolve the ambiguity. The authors argued these results indicate that such ambiguous sentences are processed more easily because they contain an antecedent for the remnant *who* that is in a normal focus position (*someone*).

Follow-up studies checked the hypothesis that focus functions to bias antecedent selection by contrasting ambiguous sentences with various focus placements (focal accent in upper case):

[9a] SOME TOURIST suspected that the hotelkeeper was hiding someone. Guess who?

[9b] Some tourist suspected that the hotelkeeper was hiding SOMEONE. Guess who?

Participants were asked to indicate which NP was the antecedent: the subject (some tourist) or the object (someone)? For sentences with subject-focus [9a], 48% of responses selected the object as the preferred reading; for sentences with object-focus [9b], 72% of responses chose the object as the antecedent (Frazier & Clifton, 1998). These results demonstrated that focus is a factor influencing how the ellipsis will be interpreted. Furthermore, the bias for the object antecedent (*someone*) is more likely to be attributable to focus, as the bias is overridden by the placement of focus on the subject.

These results were replicated and extended to definite sentences in a later study that manipulated focus using an auditory questionnaire (Carlson, Dickey, Frazier, & Clifton Jr, 2007, 2009):

[10a] ALICE insulted BILL, but I don't know who else. Double Accent

[10b] Alice inSULted Bill, but I don't know who else. Verb Accent

In sentences that accented neither the subject nor the object, the preferred interpretation remained the object reading (*I don't know who else Alice insulted*) for almost 80% of the responses. Additionally, Carlson and colleagues used syntactic structure (instead of prosodic accents) to focus either the subject or the object in a self-paced reading study:

[11a] It was Lisa who Patty praised at the ceremony, but I don't know who else.

[11b] It was Patty who praised Lisa at the ceremony, but I don't know who else.

The cleft structure puts the focus on the first, clefted element (the object *Lisa* in [11a], the subject *Patty* in [11b]). Participants indicated a preference for the object interpretation (*but I don't know who else Patty praised;* 79% of responses) in object clefts [11a]; the subject reading (*I don't know who else praised Lisa*) was favored (71%) in subject clefts [11b]. In other words, participants preferentially chose the clefted argument as the antecedent, whichever it was. These results cast doubt on the possibility that a recency effect underlined the object bias, since the preferred antecedents were not the most recent in the cleft sentences. Rather, these findings emphasized the role of focus (syntactic or prosodic) in antecedent selection in ellipsis resolution.

To summarize, an ellipsis is attributed meaning in real time; the appropriate antecedent is selected and retrieved from memory to be integrated into the sentential

context. The purpose of the current study is to extend the examination of real-time processing to a new variant of ellipsis, Sluicing, whose antecedent is perhaps the most flexible and variable of all ellipsis types. We aim to establish the basic activation patterns in sluiced sentences to provide a baseline to which future research may refer. Sluicing has already shown some promise in understanding the factors at play in ellipsis resolution, but still little is known on the construction of an interpretation for the sluiced sentence. The specific goals of this study, then, were to: 1- determine whether an entire clause (arguably the most complex of antecedents) is re-activated by the sluice; and 2- discover the point in time at which the ellipsis is resolved. To forecast our conclusions, the antecedent in Sluicing is recovered online, at a downstream point from the temporal position of the ellipsis. The timing of the operation is later than what has previously been observed in another variant of ellipsis, suggesting parallelism expectations may affect the time course of ellipsis resolution. Surprisingly, the evidence for antecedent reactivation was only partial, as one of the components of the antecedent clause was not observed in the elliptical clause. Possible explanations for the unexpected result are considered, including a role for focus in antecedent reconstruction.

Experiment 1A

Rationale

This experiment was designed to establish two facts about the processing of Sluicing: *when* is the sluice detected and *how much* of the antecedent is recovered in the

elided clause? To do so, activation of the subject and object of the antecedent clause was probed at the temporal point of the sluice and also 'downstream' from the sluice, using a cross-modal priming paradigm. We predicted that the antecedent would be re-accessed at the downstream position based on prior work reporting late effects in non-coordinated sentences (Shapiro & Hestvik, 1995).

Participants

Thirty students from San Diego State University (all females; mean age: 22.3; range: 18-48) participated in Experiment 1A for course credit. All participants were monolingual native speakers of English with normal or corrected-to-normal auditory and visual acuity. Participants had not been exposed to a second language before the age of six and had no history of neurological injury or learning disorder.

Materials

Forty sentences containing a sluice (strikethrough) such as [12] were created:

[12] The handyman threw a book to the programmer but I don't know which book ~~[the handyman threw to the programmer]~~ and no one else seems to know.

The sentences matched the following template: NP (subject) – verb – NP (non-sluiced object) – NP (sluiced object) – '*but I don't know which* (non-sluiced object) – closing segment starting with *'and'*. The closing segment was incorporated to offer ample time to

test at a position downstream from the location of the sluice (offset of *book*) while avoiding end-of-sentence wrap-up effects (Balogh, Zurif, Prather, Swinney, & Finkel, 1998). Importantly, no semantic relatedness was allowed within the sentences to prevent confounding priming effects.

The antecedent of the ellipsis (namely, the sluiced sentence) was the first clause in all sentences, minus the non-sluiced object (e.g.: *the handyman threw_ to the programmer*). We probed for the sluiced subject (*handyman*) and object (*programmer*) in the ellipsis clause; these represent the left and right edges of the antecedent clause. We chose not to probe for the verb as previous work has suggested that predicates remain activated throughout clauses (Callahan, Shapiro, & Love, submitted; De Goede, Wester, Shapiro, Swinney, & Bastiaanse, in press).

In addition to the test tokens, 85 fillers were generated. Twenty tokens were non-elliptical sentences that approximated the structure the test sentences, while the other 65 were non-elliptical constructions that varied in syntactic structure. In addition to these items, 41 yes/no questions per session were composed. The questions were presented at irregular intervals with the goal of encouraging attention to the sentences. Finally, an additional ten sentences and two questions were created to form a practice session. In short, less than 25% of the 178 sentences composing a session were test items.

Visual probes were assigned to each of the sentences. For the filler sentences, roughly half of the visual probes were English pseudowords; the presentation of these probes was randomly dispersed over the course of the sentences so as to prevent participants from predicting when the probes would appear. For test sentences, probes

were English words that were semantically related to either the antecedent's subject (sentences S1-S20, see Appendix) or to the antecedent's object (sentences S21-S40, see Appendix). The test probes were, but for one exception, the first semantic associate of the noun of interest (Subject or Object)[2]. These probes were presented at specific points in time: at the elision site (① below) and at a downstream point (500ms later; approximately at ② below):

[13] The handyman threw a book to the programmer but I don't know which book ① and no one ② else seems to know.

These positions were determined based on the temporal location of the sluice (①) and on previous findings that ellipsis is detected and interpreted some 500ms downstream from the elision site in subordinated sentences (Shapiro & Hestvik, 1995). Since the test sentences in this experiment were subordinated constructions (conjoined by 'but'), it was expected the sluice would trigger the re-activation of its antecedent after a certain delay (that is, at ②). Hence, probe position 1 served as a baseline to ensure the antecedent had decayed in activation before being re-activated by the ellipsis.

[2] The exception was the pair *doctor-nurse*, where *nurse* is the third associate of *doctor*. We thank Dr. Sarah Callahan for sharing her experimentally-built database of nouns and their semantic associates.

Design

There were eight conditions, with noun of interest (Subject, Object), probe position (PP1, PP2) and probe type (Control, Related) as factors. The complete design was counterbalanced across four lists: each test sentence appeared in every condition but for the factor Noun of Interest, which was a between-sentence factor[3]. Participants came in for two sessions, 1 week apart, and were randomly assigned a pair of scripts: in the first session, a sentence was presented at one probe position with an Object- or Subject-related probe; in the second session, the same sentence appeared at the same position but with its control probe. Within a session, test and filler sentences were ordered pseudo-randomly following the constraint that no more than three items with similar properties (filler or test, noun of interest, probe position or type, word/nonword probe) would be sequentially presented. In sum, each sentence was only heard once per session, but twice in total. Importantly, participants contributed data to all conditions albeit with different sentence/condition combinations.

Procedure

[3] This limitation is due to the nature of the stimuli, which required both a direct and indirect object (1 sluiced, 1 nonsluiced); only a small number of English verbs imperatively take two objects. Thus, the number of tokens that could meet the double-object requirement was limited (n = 20). These tokens were dedicated to the examination of the re-activation of the antecedent Object. Twenty additional sluiced sentences were designed to study the re-activation of the antecedent Subject so as to increase the sample's representativeness of the population of sluiced sentences. In this way, the sample of sluiced sentences was doubled and allowed for more confidence inferring over the population of Sluicing constructions.

A Cross-Modal Lexical Priming paradigm was used. The sentences – digitally recorded at a normal speech rate – were aurally presented through headphones to participants who were sitting in a soundproofed booth facing a computer. At a pre-determined point during the unfolding of the sentence (see Section 1.2.2), a visual probe appeared centrally on the screen for 300ms. Participants were asked to perform two tasks: 1) to indicate as quickly and as accurately as possible whether the visual probe was a word of English using a two-button box; 2) to carefully listen to the sentences and answer a comprehension question when prompted.

A session began with a practice session. When participants showed comprehension of the tasks at hand, the experiment started. Presentation software was used to present the auditory and visual stimuli and to record participants' accuracy and reaction times with millisecond accuracy.

Results

Incorrect responses ("nonword" to a real word test stimulus or failure to respond in the allotted time) were excluded, which represented 4.9% of the data[4]. Data from correct responses were compiled. As is standard in the analysis of such data, a cutoff was applied whereby reaction times (RTs) faster than 300ms or slower than 1500ms were excluded (1.5% of data).

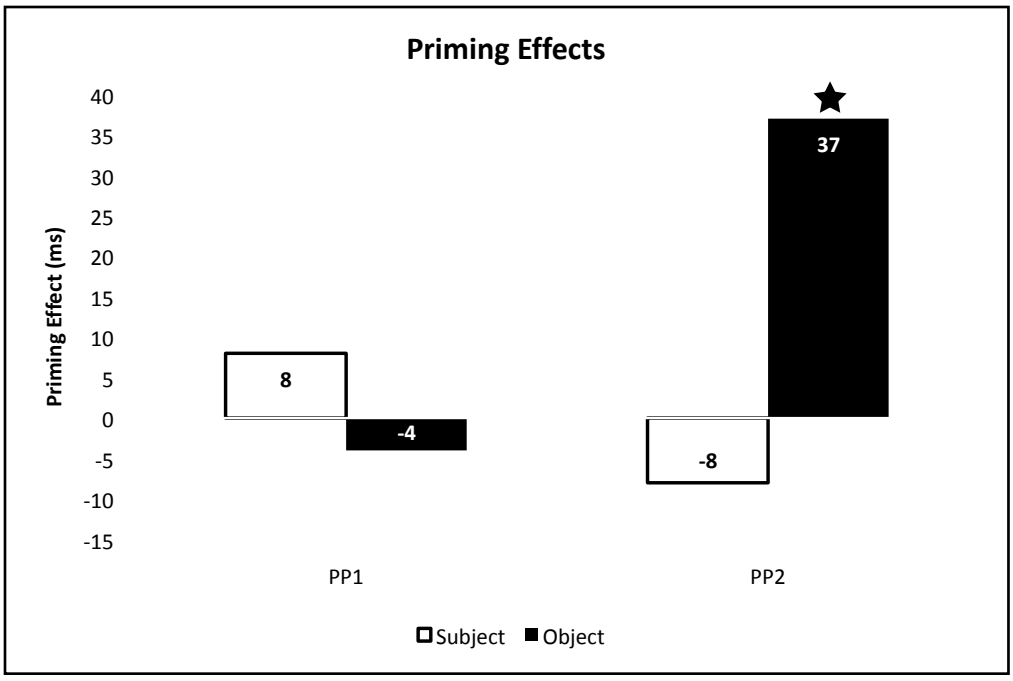
[4] Two participants did not perform satisfactorily on the lexical decision task, averaging less than 60% correct responses. Due to their demonstration of insufficient attention and/or comprehension of the task at hand, these participants were not considered in the analysis.

The observation of $RT_{related} < RT_{control}$ reflects a priming effect that is interpreted as evidence that the prime (i.e., the noun phrase of interest, Subject or Object) was activated. Table 3.1 presents the conditional means and standard deviations for each noun phrase (NP). As can be seen in Graph 3.1, priming was obtained for the Object at the downstream position. No reliable effect was observed for the Subject.

Table 3.1 Mean reaction times and standard deviations to related and control probes for the Subject and the Object at each probe position. * = control/related conditions statistically different.

NP	*Data*	*PP1* (Elision Site)		*PP2* (Downstream)	
		Control	*Related*	*Control*	*Related*
Subject	***Mean***	*711*	*703*	*719*	*727*
	(SD)	*(118)*	*(127)*	*(124)*	*(123)*
Object	***Mean***	*715*	*719*	*748**	*711**
	(SD)	*(108)*	*(125)*	*(125)*	*(110)*

Graph 3.1 Priming effects (control minus related RTs) for the Subject and the Object at each probe position. * = statistically significant effect.



An Analysis of Variance (ANOVA) was performed with subjects (F_1) and items (F_2) as random variables and with Noun of Interest (NP; Subject, Object), Probe Position (PP; PP1, PP2) and Probe Type (PT; control, related) as within-subject factors (with the exception of Noun of Interest, which was a between-item factor in the F2 analyses).

A main effect of Probe Position (F_1 (1,27) = 5.29, $p < 0.05$), as well as a main effect of Probe Type (F_2 (1,19) = 3.44, $p = 0.079$) were observed. A marginally significant three-way interaction between NP, Probe Position and Probe Type was also revealed (F_1 (1,27) = 3.49, $p = 0.07$). To explore the nature of this interaction, 2-way ANOVAs were performed for each NP separately. For Object, a near-significant Probe Position x Probe

Type interaction was found (F_1 (1,27) = 3.25, p = 0.08). No main effect or interaction was observed with Subject.

We also computed one-tailed planned comparisons to directly address test the prediction of late re-activation of the Object and of the Subject. Our expectations were partially supported: Object-related probes were indeed responded to faster than control probes at the downstream position (subject-based: t_{27} = 2.30, p < 0.05; item-based: t_{19} = 2.20, p < 0.05), and not at the elision site (subject-based: t_{27} = -0.25, p > 0.05; item-based: t_{19} = 0.05, p > 0.05). However, for Subject, the priming effect was statistically significant neither at the elision site (subject-based: t_{27} = 0.55, p > 0.05; item-based: t_{19} = 0.60, p > 0.05) nor at the expected downstream position (subject-based: t_{27} = -0.53, p > 0.05; item-based: t_{19} = -0.30, p > 0.05).

In sum, the subject- and item-based analyses indicate that the antecedent Object is re-activated in the elliptical clause. By contrast, no evidence for Subject re-access was found, contra our predictions.

Discussion of Experiment 1A

Experiment 1A aimed to determine if and when the antecedent is re-accessed in Sluicing. Activation of the Subject and the Object was probed at the elision site (offset of *which book*) and at a downstream point. Priming for the Object was obtained at the later position (PP2), but not for the Subject. We assume that it was the processing of the sluice that triggered the re-activation of the antecedent's Object rather than residual activation

from the overt appearance in the antecedent clause because there was no activation found at the earlier (PP1) position; this was, as predicted.

Unexpectedly, the subject was *not* found activated at either probe position. Before we speculate on possible explanations for the absence of Subject reactivation in Sluicing, we designed Experiment 1B to examine if there were methodological reasons for this null effect. More precisely, we wanted to test the possibility that the Subject of the antecedent, due to its position in the sentence (first noun phrase), could have been too difficult to identify properly by the participants (perhaps because of a lack of attention so early on in the sentence), which would have made it impossible for them to retrieve the noun phrase later in the sentence. By the same token, we aimed to confirm that our Subject-related probes *could* yield priming effects, that is, that they were close semantic associates of the prime (the Subject).

Experiment 1B

Rationale

The lack of priming for the Subject in Experiment 1A could arise for two reasons: 1) processing a sluice does not necessarily involve the re-activation of the entire antecedent, or 2) the stimuli used disallowed activation of the subject because of its early position in the sentence, which may have resulted in inattention by the participant. Experiment 1B directly addressed these issues by probing for the Subject at its offset in

the antecedent clause and exploring the relation between Subject identification and antecedent re-activation in the elliptical clause.

Methods

Experiment 1B used exactly the same materials and recordings as in Experiment 1A so as to reproduce the conditions under which participants were tested. We modified the design to include a probe position at the offset of the Subject in the antecedent clause while keeping the downstream position in the elliptical clause. We also probed for the Object as a control condition.[5]

The same number of conditions was used as in Experiment 1A, and the factors remained the same. The scripts were modified to replace Probe Position 1 (offset of 'book') with either the offset of the Subject or of the Object, depending on the sentence. Hence, across lists, sentences appeared in all conditions (except for noun of interest, which was a between-item factor) as in Experiment 1A. In the current experiment, participants only came in for one session but provided data in each condition.

Thirteen participants (all females; mean age: 21.3; range: 20-26) meeting the same criteria as in Experiment 1A and who had not participated in Experiment 1A were run on the present experiment.

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[5] Hence, the factor Probe Position had two levels (Offset and Downstream) but the exact timing of the offset position differed between noun phrases (Ⓢ: Subject offset. Ⓞ: Object offset. :② Downstream position from Experiment 1A, 500ms after the offset of 'book'): E.g.: The handyman Ⓢthrew a book to the programmer Ⓞ but I don't know which book ~~[the handyman threw to the programmer]~~ and no one ② else seems to know.

Results

Our goal was to establish whether participants who had identified the overt Subject showed re-activation in the elliptical clause and conversely, whether participants who demonstrated antecedent reactivation (via Object priming) showed evidence of having processed the Subject in the antecedent clause. We thus analyzed the data in two ways: first, by looking at the activation patterns in the elliptical clause in participants who evinced recognition of the Subject in the antecedent clause; and second, by ensuring that participants who re-activated the antecedent in the elliptical clause had successfully processed the Subject in the antecedent clause.

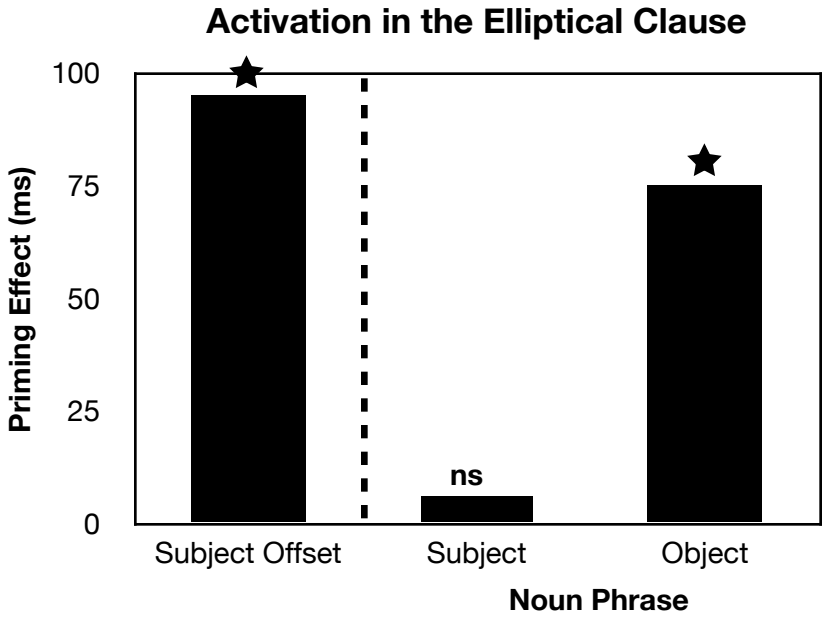
Analysis 1:

Participants showing a priming effect at Subject's offset

In this analysis, we aimed to determine if Subject re-activation would be observed in cases where the overt Subject had been demonstrably recognized.

Participants for whom $RT_{rel} < RT_{ctrl}$ at the Subject's offset were selected. The data from six participants met the criterion and were selected for further analysis. Conditional priming effects (control minus related RTs) are depicted in Graph 3.2. Unsurprisingly, the priming effect at the Subject's offset was statistically significant (control: 670ms vs. related: 575ms; $t_5 = 3.34$, $p < 0.05$, one-tailed).

Graph 3.2 Priming effects (control minus related RTs) in the elliptical clause for the Subject and the Object. The criterial effect at the Subject's offset is depicted on the left side of the dashed line. ns = nonsignificant. *= statistically significant.



Despite the clear evidence that these participants had recognized the Subject when they heard it, no evidence for its activation in the elliptical clause was found (control: 643ms vs. related: 649ms; $t_5 = 0.81$, $p > 0.05$, one-tailed). In fact, only two participants showed a control-related difference in the right direction. That is, despite having successfully processed the overt Subject, participants still did not show priming for the Subject in the elliptical clause. This lack of effect further contrasts with a reliable priming effect in 5 out of 6 participants for the Object in the elliptical clause, which confirms that the sluice had been processed and the antecedent, re-accessed (control: 714 vs. related: 638ms, $t_5 = 2.87$, $p < 0.05$, one-tailed).

The findings from Analysis 1 suggest that participants could clearly comprehend the material in the antecedent clause. Even so, the fact that they had done so

did not influence the activation patterns in the elliptical clause: only the antecedent Object seemed to be recovered.

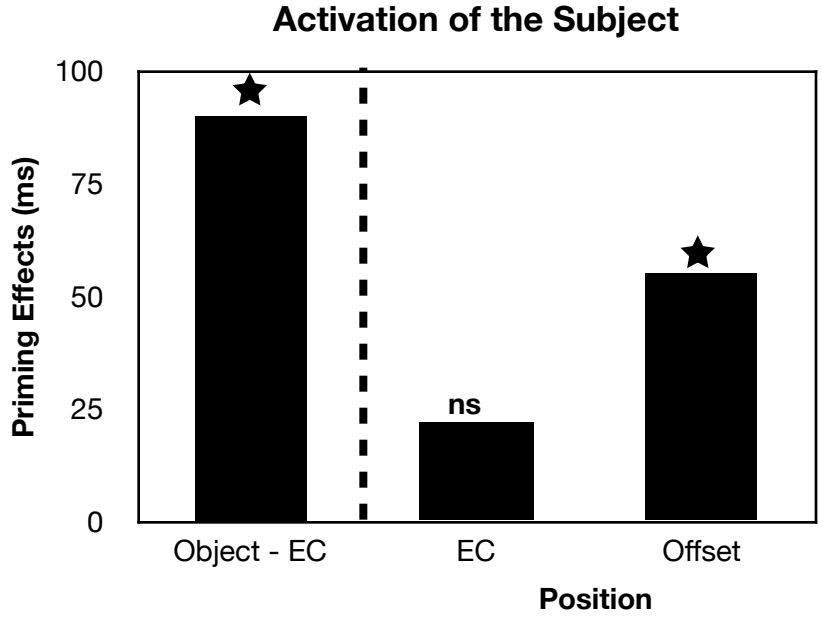
Analysis 2:

Participants showing a priming effect in the elliptical clause

To complement the first analysis, we aimed to ensure that participants who re-accessed the antecedent in the elliptical clause (as evinced by a priming effect for the Object) had been able to clearly identify (and encode) the Subject in the antecedent clause.

Participants for whom the Object's $RT_{re\ l} < RT_{ctrl}$ in the elliptical clause were selected. A new dataset was formed from the data of six participants who met the criterion. Conditional priming effects (control minus related RTs) are depicted in Graph 3.3. Here again, statistical significance was reached for the criterial priming effect (control: 655ms vs. related: 566ms; $t_5 = 4.16$, $p < 0.01$, one-tailed).

Graph 3.3 Priming effects (control minus related RTs) for the Subject at both probe positions. The criterial effect (Object activation in the elliptical clause) is depicted on the left side of the dashed line. EC = elliptical clause. ns = nonsignificant. *= statistically significant.



Clearly, these participants had recovered the antecedent Object in the elliptical clause, confirming they had processed the sluice. Still, the priming effect for the antecedent Subject was not statistically reliable in the elliptical clause (control: 606ms vs. related: 584ms; $t_5 = 0.31$, $p > 0.05$, one-tailed). By contrast, a facilitatory effect was observed at the Subject's offset, indicating these participants had detected the noun phrase in the antecedent clause (control: 602ms vs. related: 547ms; $t_5 = 2.77$, $p < 0.05$, one-tailed). Out of the 5 participants who showed a priming effect for the Subject at its offset, only 3 (i.e., half the participants) had a [control-related] difference in the right direction in the elliptical clause.

The results of Analysis 2 thus indicated that antecedent recovery involved only the Object, despite the confirmation that participants had successfully heard and identified the overt NP in the antecedent clause.

In summary, Experiment 1B replicated the patterns observed in Experiment 1A, namely that the Object but not the Subject of the antecedent is recovered in the elliptical clause. Furthermore, Analyses 1 and 2 suggest that the lack of a priming effect for the Subject in the elliptical clause was not likely due to participants' failure to attentively listen to the stimuli, since evidence was obtained that they had processed and recognized the overt Subject in the earlier part of the sentence. Lastly, the validity of our Subject-related probes is supported by the priming effects observed at the offset: if the probes had not been close semantic associates of the prime (i.e., the Subject), no priming should have been obtained.

Discussion of Experiment 1B

Experiment 1B was designed to address potential methodological reasons that the antecedent Subject was not observed in the elliptical clause in Experiment 1A. We aimed to determine whether participants discerned and identified the overt NP in the antecedent clause to ensure the information was available for retrieval later in the sentence. Our results indicate that, indeed, participants who revealed activation for the Subject at its overt appearance in the antecedent clause still did not evince activation for the Subject in the ellipsis clause. Furthermore, participants who showed activation for the Object in the ellipsis clause did not show similar patterns for the Subject in the ellipsis clause, yet they

did reveal activation for the Subject at its overt appearance in the antecedent clause. Thus, the lack of priming of the Subject in the ellipsis clause cannot be because the participants simply did not have time to pay attention to the Subject when it was rapidly encountered in the first position. A secondary interpretation of these patterns also strongly suggests that the Subject-related probes were sufficiently close in semantic association to the prime (i.e., the Subject) to yield priming effects.

Overall then, Experiment 1B offers evidence against a methodological shortcoming as the reason for the lack of Subject priming effect in the elliptical clause. Hence, it seems to be the case that the Subject of the antecedent clause is not re-activated in Sluicing.

General Discussion

The current study extended the examination of elliptical sentences to Sluicing. In Sluicing constructions, a constituent is unpronounced (strikethrough below):

[*The handyman threw a book to the programmer*]$_{AC}$ *but I don't know which book* ~~*(the handyman threw to the programmer)*~~$_{EC}$.

To be understood, sluiced sentences must be interpreted based on the antecedent clause (AC; square brackets above). The purpose of the study was to determine if the antecedent clause is re-activated in the elliptical clause (EC) and if so, at what point in time.

Experiment 1A revealed that processing a sluiced sentence does trigger re-access of its antecedent. Yet unexpectedly, the antecedent clause was not re-activated in its entirety: namely, only priming for the Object (*programmer*) was obtained.

We first turn to the observed re-activation of the Object in the elliptical clause. This finding is directly in line with the literature on ellipsis and on anaphora where it has been repeatedly demonstrated that antecedent re-activation occurs as soon as the referent-seeking element is processed (e.g., Nicol, 1988; Shapiro & Hestvik, 1995; Swinney, Ford, Frauenfelder, & Bresnan, 1987).

Moreover, the current study determined for the first time the exact timing of the ellipsis detection/antecedent re-access in Sluicing: the processing system postulates the existence of the elided clause *after* its temporal position in the sentence (namely, the offset of *which book*). We note here that our Sluicing stimuli were 'but'-coordinated constructions. The type of conjunction in elliptical sentences seems to be related to the time course of ellipsis resolution. In effect, ellipses in 'and'-coordinated constructions are posited earlier (i.e., at their temporal position) than in constructions otherwise conjoined (Shapiro & Hestvik, 1995; Shapiro et al., 2003; Poirier & Shapiro, submitted).

In constructions not conjoined by 'and' (such as the stimuli in the present study), the delay observed seems to be due to the necessity to infer the ellipsis from sentential context: because there are no overt cues hinting to the upcoming presence of an ellipsis, the parser does not expect an elided phrase. Hence, it is only after parsing the post-ellipsis segment that the phrase structure violation (i.e., the absence of a phrase — the elided phrase) is detected. This violation leads the processor, in turn, to posit that there is

a ‘missing’ element. Consequently, the parser posits the ellipsis later than at its temporal position, after having processed enough post-ellipsis input to detect the phrase structure violation. Although the exact duration of that post-ellipsis time window is currently unknown, neurophysiological evidence suggests it could be as short as 100ms (Kaan, Wijnen, & Swaab, 2004). As minimal this delay is, it still results in the ellipsis being postulated after its temporal location in the sentence, explaining why antecedent reactivation is observed at a downstream point.

If this time window is required to posit the ellipsis, how can early effects be observed in ‘and’-coordinated sentences? It has been shown that the conjunction ‘and’ induces expectations of parallelism between conjuncts (Knoeferle, 2007). A considerable amount of evidence has accumulated on the effect of Parallelism in nonelliptical clauses; many studies have reported faster processing of a second conjunct following a parallel, first conjunct (Apel, Knoferle, & Crocker, 2007; Frazier, Munn, & Clifton, 2000; Frazier, Taft, Roeper, Clifton, & Ehrlich, 1984; Knoeferle & Crocker, in press; Mauner, Tanenhaus, & Carlson, 1995; Pickering, Branigan, Cleland, & Stewart, 2000). Thus, parallelism may function as a heuristic used by the processing system to facilitate parsing.[6] However, the facilitation effect is limited to coordinated sentences that are joined by parallelism-implying conjunctions, such as ‘and’ and ‘while’, but not ‘but’ (Knoeferle, 2007). Returning to ellipsis, early ellipsis resolution has been observed early in ‘and’-conjoined sentences, and later in sentences otherwise conjoined (by

[6] The Parallelism effect occurs in comprehension and in production, although the mechanisms involved might differ between modalities. See for example Bock, 1986; Knoeferle & Pickering, in press; and Pickering & Ferreira, 2008 for a related discussion on syntactic priming.

'because' or 'but'). It thus seems that the expectation of parallelism in 'and'-coordinated sentences speeds up the postulation and resolution of ellipsis. Two mechanisms could potentially underlie such facilitation: the expectation of parallelism can render the antecedent already accessible at the temporal location of the ellipsis by re-activating it before the ellipsis is encountered. In effect, studies have reported activation of first-conjunct material as soon as the conjunction 'and' was processed (Callahan et al., submitted; Poirier & Shapiro, submitted). Alternatively, the processor could attempt to parse the second conjunct identically to the first; at the point in time where the structure differs from the first clause (that is, at the temporal location of the ellipsis), an elided constituent would immediately be postulated.

Returning to the observation of Object reactivation in the present study, this finding seems to indicate that the antecedent is re-accessed in Sluicing much like other anaphora (verb-phrase ellipsis, pronouns, traces, etc). By contrast with verb-phrase ellipsis, however, the antecedent recovered was not, strictly speaking, the syntactically-defined antecedent. In effect, no reliable evidence of Subject reactivation was obtained in the elliptical clause. Thus, it cannot be confirmed from these results that the entire antecedent is reconstructed in Sluicing. Any tentative conclusion is based on a null result (i.e., *absence* of Subject activation), but we cautiously consider possible explanations for this apparent partial antecedent recovery.

So, why would the Subject not be re-activated in the elliptical clause, especially considering the potentially adverse effect of only partially recovering the meaning of the elided constituent might have on comprehension? One possibility is that the Subject NP

may be too far back in the temporal stream (due to its sentence-initial position) for it to be successfully recovered. This possibility is not strongly supported experimentally. For example, in nonelliptical sentences, Subject re-activation was observed, despite about 26 syllables separating the sentence-initial Subject and its reactivation site (Friedmann, Shapiro, Taranto, & Swinney, 2008). In Ellipsis, previous studies using the speed-accuracy trade-off paradigm demonstrated that the distance between an ellipsis and its antecedent does not increase the processing load associated with antecedent retrieval (Martin & McElree, 2008).[7] Relatedly, antecedent length did not affect interpretation accuracy or speed (Martin & McElree, 2008). Taking into consideration that the maximal Subject-Ellipsis distance and antecedent length tested in the work above mentioned by far exceeded those in the current study, it is unlikely that the Subject here was too far from the ellipsis to be retrieved later in the sentence.

Another possibility regards the Subject's syntactic role in the antecedent clause. Subjects are external arguments of the verb (and objects, internal arguments). Very little psycholinguistic work has investigated the external-internal argument distinction. Linguistic analyses have argued that external arguments are not selected by the verb (in contrast with internal arguments), but rather by the entire verb phrase (the phrase consisting of the verb and its object; e.g.: Marantz, 1984). Moreover, several languages such as Spanish, Italian, Arabic, Finnish, Chinese, Japanese and Hindi (among others) allow for the absence of overt subjects in sentences, whereas only a handful permit the

[7] However, a slight decline in accuracy was observed. The authors argue the decrease is probably due to the interference in retrieving the antecedent from memory.

same for objects. External arguments thus seem more disposable than internal ones; the parser could disregard the 'superfluous' Subject NP when reconstructing the ellipsis. This argument, however, is inconsistent with studies that found subject/external argument re-activation in anaphoric relations (Friedmann, Shapiro, Taranto, & Swinney, 2008; Nicol, 1988; Zurif, Swinney, Prather, Solomon, & Bushell, 1993; Bever & Santz, 1997; among others), including in elliptical constructions (Poirier & Shapiro, submitted; Koeneman et al., 1998). Hence, the function of the external argument does not seem to preclude re-activation of a noun phrase. Nonetheless, it cannot be ruled out that the complexity of the antecedent in Sluicing imposes restrictions on the parser that are otherwise absent. For instance, it is conceivable that the parser, in a need for economy and faced with high processing loads, would elect to drop a phrase that is dispensable – the external argument.

We thus now turn to the possibility that antecedent complexity affects antecedent retrieval. Namely, it may be the case that in Sluicing, the 'grain size' of the antecedent prevents full antecedent reconstruction (at least online). This possibility would be consistent with recent findings from aphasia that suggest antecedent complexity may increase the burden on the processing system. In effect, anterior-lesioned Broca's patients can retrieve noun phrases to assign to referent-seeking elements (albeit after a delay; Love, Swinney, Walenski, & Zurif, 2008), but fail to re-activate an antecedent verb phrase in verb-phrase ellipsis (Poirier, Shapiro, Love, & Grodzinsky, 2009). Considering that verb phrases represent more material and structure than noun phrases, it is possible that the amount of material to retrieve overwhelms the processing system of these

patients.[8] However, speed-accuracy trade-off studies of ellipsis report that antecedent complexity affects neither speed nor accuracy (Martin & McElree, 2008).[9] Furthermore, other studies have repeatedly reported that antecedent complexity does not increase processing loads in ellipsis (Frazier & Clifton, 2000, 2001). Hence, the support for the view that antecedent complexity affects ellipsis resolution is equivocal.

Nonetheless, we believe the issue of complexity should be further scrutinized. For one thing, the conclusion that antecedent complexity does not affect antecedent retrieval is based on a null result (i.e., the absence of increased reaction times with more complex antecedents). It is thus possible that there are indeed complexity effects, but that they have thus far been missed. One reason complexity effects might not have been detected could involve methodological considerations. In effect, complexity effects have only been studied in the written modality (in self-paced reading, speed-accuracy trade-off and eye-tracking paradigms) and in stimuli where the ellipsis is sentence-final (Frazier & Clifton, 2000, 2001; Martin & McElree, 2008). These paradigms might have been unable to detect complexity effects, perhaps due to the modality or the presentation style. For example, all previous studies on complexity effects presented their stimuli in a segmented, phrase-by-phrase style that unnaturally chunks the input. This chunking process, might, in turn, facilitate the retrieval of large amounts of information. In addition, these studies investigated ellipsis in sentence-final positions. Considering that

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[8] Alternative explanations for patients' failure to reactivate the antecedent include potential processing loads due to a semantic or discourse component in verb-phrase ellipsis and a possible failure to detect the covert constituent in the first place.

[9] With one potential exception: a higher number of discourse referents (overt noun phrases) may decrease accuracy levels.

end-of-sentence wrap-up effects have been shown to trigger reactivation of previously encountered material (Balogh et al., 1998), it is possible that processing costs incurred by the antecedent retrieval operation could have been masked by ellipsis-unrelated, wrap-up activation processes. On the other hand, the present study aurally presented the sentences in a continuous fashion, and the stimuli were carefully constructed so that the ellipsis would not appear sentence-finally. If any of these methodological factors prevented the detection of (potentially minute) complexity effects in previous experiments, the partial antecedent reconstruction found in the present study could, in principle, reflect complexity effects.

Along the same lines, complexity effects might exist if the definition of complexity is reconsidered. For example, there are two factors that do not increase processing loads, but that negatively affect ellipsis interpretation: distance and number of referential noun phrases (NPs). Speed-accuracy trade-off studies have reported a slight decrease in accuracy levels with higher numbers of (NPs) in the antecedent and with more distance antecedents (Martin & McElree, 2008). These effects could be due to increased interference during antecedent retrieval, as more material intervenes between the antecedent and the ellipsis in these cases. Furthermore, a memory-based parsing model of sentence comprehension has proposed that processing difficulty results from the difficulty in retrieving phrases from memory (Lewis, Vasishth, & Van Dyke, 2006). Hence, the patterns of activations observed in Sluicing could be attributed to a complexity effect defined in terms of inference during memory retrieval. In effect, the antecedent in Sluicing would create greater interference due to the higher number of NPs

in a clause compared to other antecedents (such as verb phrases in Verb-Phrase Ellipsis). Moreover, interference would differentially affect the Subject and the Object in Sluicing: the Subject is farther from the ellipsis and thus potentially subject to more interference than the Object. In this way, the processor would fail to retrieve the Subject in Sluicing due to interference.

However, in the memory-based model referred to above, interference is associated with processing costs that are detectable in reaction times. Still, neither antecedent-ellipsis distance nor number of referential NPs affects processing speed, which is inconsistent with an interference-based processing load (Martin & McElree, 2008). Additionally, if the activation patterns in Sluicing are attributable to inference-induced processing costs, these factors (distance and number of referential NPs) should apply to non-clausal antecedents (e.g., verb phrases) as well. That is, non-clausal antecedents with a similarly high number of NPs − some of which are distant from the ellipsis − would be expected to show interference-related processing difficulty. Yet, elliptical sentences with such long non-clausal antecedents are not processed more slowly or less accurately than elliptical sentences with shorter antecedents (Martin & McElree, 2008, Exp. 4). It thus does not appear to be the case that interference is responsible for the lack of Subject re-activation in Sluicing: should the processor fail to retrieve the Subject due to interference, a comparable interference should be reflected in longer reaction times or lower accuracy levels with other ellipses. Again, neither was found in antecedents with properties similar to the antecedent clause in Sluicing (Martin & McElree, 2008, Exp. 4). In short,

interference as an index of complexity does not straightforwardly account for the pattern of results observed in Chapter 4.

Returning to the definition of complexity, there is one more aspect in which the antecedent in Sluicing differs from antecedents in other anaphoric relations. As mentioned above, all types of anaphora studies thus far have been reported to re-activate their syntactically-defined antecedents (noun phrases, verb phrases, etc.). Thus, the clause in Sluicing would be the first case of an antecedent not retrieved online by healthy participants. It is hence a logical possibility that the phrasal category (verb, noun phrase, verb phrase, etc.) of the antecedent in Sluicing hampered the reactivation process. This possibility lays on two important premises: 1) a clause (IP) differs in one relevant way from other phrases (and not solely in complexity as previously defined in investigations of complexity effects, e.g., number of noun phrases in the antecedent); 2) there is a systemic reason for the divergent patterns between Object and Subject reactivation in Sluicing.

One hypothesis that would meet both requirements regards the involvement of inflectional nodes in the syntactic tree. In effect, only IPs implicate the inflectional nodes above the verb phrase. It is thus conceivable that retrieving information from inflectional nodes is particularly costly, perhaps to a point where the parser either elects to or cannot access this information. If this were the case, only information below the inflectional nodes would be retrieved by the parser. In ellipsis resolution, the result would be the re-activation of any antecedent lower than the inflectional nodes (e.g.: a verb phrase in VPE). In Sluicing, only the object would be reactivated; the subject would not be

retrieved due to its position high in the inflectional nodes of the syntactic tree. This hypothesis is interestingly similar to the Tree Pruning Hypothesis (TPH; Friedmann & Grodzinsky, 1997; Friedmann, 2006). The TPH describes the functional breakdown in agrammatic production by suggesting inflectional nodes are 'pruned' from the syntactic tree, accounting for a myriad of observations on the limited output of these patients. In that sense, both hypotheses propose that inflectional nodes impute high processing costs that would lead to patients' impairments in production and the partial antecedent retrieval in Sluicing.

Lastly, an alternative view on the lack of Subject re-activation in Sluicing reconsiders the assumption that a unit smaller than the antecedent clause is reconstructed in the elliptical clause. One possible explanation could be that the elided material is recovered as a clause, but in a syntactic form that would exclude the Subject. In effect, if the Subject is not re-accessed, how can we be sure the underlying meaning of the sluice involves the Subject? For instance, the sluice could be interpreted in the passive voice:

[14] The handyman threw a book to the programmer, but I don't know…

a. which book ~~the handyman threw __ to the programmer.~~ Active Voice

b. which book ~~was thrown (by the handyman) to the programmer.~~ Passive Voice

Antecedent-ellipsis mismatches such as [14b] are dispreferred or more costly to process compared to their matching counterpart [14a] (Frazier & Clifton, 2005; Dickey & Bunger, under revision). Still, antecedent-ellipsis mismatches can be acceptable to

various degrees and are in fact fairly common (Tanenhaus & Carlson, 1990; Kehler, 2000; Arregui et al., 2006; Kertz, 2008; see also Potsdam, 2007 for evidence in Sluicing). Considering that syntactic detail fades rapidly in memory (Sachs, 1967), the structure of the first clause may not be available to the processor when computing an interpretation for the ellipsis. The parser might, then, reconstruct the elided clause in the passive voice, a syntactic form that can grammatically exclude the agent of the action (the by-phrase in parentheses in [14b]). The passive form would naturally maintain the (syntactic and prosodic) focus on the nonsluiced object (*which book*) by making it the subject of the passive clause (*[which book]$_{subject}$ was thrown to the programmer).* Supposing the clause would be reconstructed in this short passive form, no reactivation of the Subject *handyman* would be expected in the elliptical clause. This explanation is speculative, of course, but finds some support by previous research demonstrating an important role of focus in processing (see Introduction) and would reconcile the findings of this study with the literature on anaphora. This hypothesis could be tested in future work by using sentences that do not place focus on an object (e.g.: sluiced sentences with *why* as a remnant: The *handyman threw a book to the programmer, but I don't know why ~~the handyman threw a book to the programmer~~*). In these conditions, the parser would be expected to reconstruct sluiced sentence in its original active form. This experiment is currently under way in our laboratory.

Clearly, more research is needed to clarify the effect – if any – of antecedent complexity on real-time ellipsis resolution and on the computation of an interpretation for a sluiced sentence. In sum, the puzzling lack of Subject re-activation, if replicated, will

require careful experimentation to determine its cause. Assuming the null result holds, the absence of the Subject in the elliptical clause is problematic for syntactic and nonsyntactic accounts of ellipsis. In effect, both types of accounts would predict that the entire antecedent would be used in the computation of an interpretation for the ellipsis. Likewise for processing accounts: a cost-free copy mechanism or a content-addressable memory pointer assume there are no processing costs associated with syntactic complexity and would consequently predict that a more complex antecedent – such as a clause – could be recovered in its entirety in the elliptical clause.

In conclusion, the current study has established that the antecedent in Sluicing is re-accessed (although maybe only partially) as the sentence unfolds, similarly to Verb-Phrase Ellipsis and other anaphoric relations. The point in time at which the ellipsis is interpreted in Sluicing offers additional support to the hypothesis that parallelism expectations facilitate ellipsis resolution. We believe that the patterns of activation reported here can serve as a baseline for further research investigating the effects of antecedent properties on the processing and comprehension of ellipsis.

Appendix

S1 The **ambassador** loaded the bus with criminals but I don't know which bus and no one else was there to see.

C painting R country

S2 The **actor** leased a house to the lawyer but I don't know which house and I was on vacation when it happened.

C horse R movie

S3 The **skier** brought a casserole to the neighbor but I don't know which casserole and I don't really care.

C movie R snow

S4 The **jockey** passed a ball to the teenager but I don't know which ball and I had a broken arm so I couldn't play.

C snow R horse

S5 The **artist** poured a soda for the mentor but I don't know which soda and I was talking to Mary so I didn’t notice.

C country R painting

S6 The **astronaut** sold a scooter to the gardener but I don't know which scooter and I heard the wheel fell off.

C ring R space

S7 The **juggler** served a martini to the surgeon but I don't know which martini and I already had too many to care.

C hammer R ball

S8 The **chemist** showed an apartment to the exterminator but I don't know which apartment and no one else was home to see.

C ball R beaker

S9 The **handyman** threw a book to the programmer but I don't know which book and no one else seems to know.

C beaker R hammer

S10 The **boxer** mailed a present to the teammate but I don't know which present and I couldn't be there to see it opened.

C space R ring

S11 The **author** shipped a car to the new owner but I don't know which car and I was not able to afford it.

C pool R book

S12 The **captain** delivered a telegram to the musician but I don't know which telegram and got there too late to see.

C book R ship

S13 The **worker** splashed juice on the translator but I don't know which juice and the shirt got stained.

C ship R job

S14 The **sailor** sprayed confetti on the judge but I don't know which confetti and there was so many different colors that no one could tell.

C job R boat

S15 The **swimmer** owed a book to the salesman but I don't know which book and I don't really care.

C boat R pool

S16 The **teacher** rented a golf cart to the assistant but I don't know which golf cart and I already own one.

C building R student

S17 The **locksmith** bought a boat for the reporter but I don't know which boat and I can't wait to go for a ride.

C nurse R key

S18 The **cook** saved a seat for the photographer but I don't know which seat and I was already sitting across the room.

C key R food

S19 The **doctor** wrote a letter to the hitchhiker but I don't know what letter and I couldn't care less.

C food R nurse

S20 The **architect** reserved a table for the caretaker but I don't know which table and the place was so crowded so it was a good thing.

C student R building

S21 The fisherman put a hat on the **guide** but I don't know which hat and I was playing soccer so I didn't notice.

C business R tour

S22 The barber assigned a project to the **dentist** but I don't know which project and I was already assigned my own.

C weather R teeth

S23 The builder discussed the football game with the **doorman** but I don't know which game and I didn't get to hear the ending score.

C teeth R hotel

S24 The designer returned a gift to the **meteorologist** but I don't know which gift and I heard that it was expensive.

C hotel R weather

S25 The publisher transferred a check to the **entrepreneur** but I don't know which check and I wasn't affected by it so I don't care.

C tour R business

S26 The custodian gave a drink to the **policeman** but I don't know which drink and I think that it might have been Sprite.

C money R gun

S27 The colleague handed a surfboard to the **mailman** but I don't know which surfboard and I heard that Bob was giving surf lessons.

C security R letter

S28 The apprentice introduced a student to the **pianist** but I don't know which student and I didn't get to go.

C gun R music

S29 The soldier traded a baseball card with the **millionaire** but I don't know which card and I don't know who even likes baseball.

C music R money

S30 The butcher offered a sandwich to the **guard** but I don't know which sandwich and I already had my own.

C letter R security

S31 The commander promised a ring to the **celebrity** but I don't know which ring and I heard the answer was no.

C train R fame

S32 The priest placed a jacket on the **king** but I don't know which jacket and I hope it was warm because it was snowing outside.

C state R crown

S33 The veterinarian read a story to the **executive** but I don't know which story and I was too busy reading my own to hear.

C crown R office

S34 The electrician sent a package to the **governor** but I don't know which package and I don't really care.

C fame R state

S35 The speaker stuck a nametag on the **conductor** but I don't know which nametag and I heard there ended up being a kind of mix up.

C office R train

S36 The manufacturer stored a box for the **bellboy** but I don’t know which box and I hope that it didn't get stolen.

C family R luggage

S37 The hiker loaned a bike to the **clown** but I don't know which bike and I heard it never got returned.

C sheep R nose

S38 The manager issued a key to the **blacksmith** but I don't know which key and I already had my own set.

C nose R metal

S39 The writer donated a check to the **shepherd** but I don't know which check and I don't think it was worth very much.

C metal R sheep

S40 The cowboy taught the game to the **relative** but I don't know which game and I didn't get to play.

C luggage R family

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CHAPTER 4

The Online Processing of Verb-Phrase Ellipsis in Aphasia

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The On-Line Processing of Verb-Phrase Ellipsis in Aphasia

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Abstract We investigated the on-line processing of verb-phrase ellipsis (VPE) constructions in two brain injured populations: Broca's and Anomic aphasics. VPE constructions are built from two simple clauses; the first is the antecedent clause and the second is the ellipsis clause. The ellipsis clause is missing its verb and object (i.e., its verb phrase (VP)), which receives its reference from the fully specified VP in the antecedent clause. VPE constructions are unlike other sentence types that require displacement of an argument NP; these latter constructions (e.g., object-relatives, wh-questions) yield either on-time or delayed antecedent reactivation. Our results demonstrate that Anomics, like unimpaired individuals, evince reactivation of the direct object NP (within the VP) at the elided position. Broca's patients, on the other hand, do not show reactivation of the antecedent. We consider several interpretations for our data, including explanations focusing on the larger 'grain size' of the reconstructed material in the ellipsis clause, the properties of the auxiliary that carries tense and agreement features, and the possibility that the cost-free syntactic copy procedure claimed to underlie VPE may be modulated by the functional deficit in Broca's aphasia.

Keywords Aphasia · Sentence processing · Verb-phrase ellipsis · Aphasia classification

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Introduction

Sentence processing experiments have typically used different sentence types as a means to examine underlying operations. These constructions have been characterized as canonical and simple in the language of interest (in English, Subject–Verb–Object), or non-canonical and complex, often containing displaced constituents that yield, for example, Object–Subject–Verb word order in English. The goal has been to illuminate processes underlying normal comprehension, and how these go awry in aphasia. In this paper we describe a study examining sentence comprehension in aphasia that uses a construction type that is not so easily divisible into these categories. We used sentences that contain *ellipsis*, forms in which a part is missing but whose meaning can be readily reconstructed.

To see what we have in mind, consider the following sentence, known as a verb-phrase ellipsis (VPE).

1. [The waitress kissed the customer] and [the bartender did ~~<kiss the customer>~~ too].

This sentence is built from two simple clauses, conjoined with *and*. The first is the *antecedent clause*; the second the *ellipsis clause*. The ellipsis clause is missing its verb and object (i.e., its VP, depicted above with strikethrough lexical material), and the only remaining verbal part is the bare auxiliary *did* that carries tense and agreement but no verbal meaning. Despite the fact that several words are missing in this second clause, listeners recover the meaning of the missing VP clearly and unambiguously. VPE is subject to a Parallelism constraint, which forces the elided clause to parallel the antecedent clause. It is by virtue of this constraint that we can reconstruct the meaning in (1) correctly: Parallelism ensures that we do not take the missing part of (1) to mean, e.g., that 'the bartender shot the customer' instead of the semantically appropriate interpretation, 'the bartender kissed the customer'. Indeed, healthy adults have been reported to perform at an accuracy level of 97% in self-paced reading and in a sentence verification paradigm testing comprehension of VPE (Bélanger 2004). This demonstrates a remarkable capability of our sentence processor: it can complete missing information by leaning on the overt VP from the antecedent clause, even though this information is not adjacent to the missing part. It can do so, moreover, despite the fact that by the time the ellipsis is noticed (for example, when the word *too* is encountered), the overt VP from the antecedent clause is long gone in the temporal stream. How listeners–those with aphasia–go about the process of 'filling in' such missing material is the focus of this study. Why this is an important and potentially illuminating issue will be addressed below; first, however, we briefly review some relevant background.

Linguistic accounts of VPE classify the link between the phonologically empty VP (*the bartender's* action in (1) above) and the antecedent VP as either syntactic, semantic, or discourse-based (Dalrymple et al. 1991; Fiengo and May 1994; Hardt 1993, 1999; Johnson 2001; Kehler 2000; Lobeck 1995; Merchant 2001; Sag 1976; among others). Several of these accounts can initially be separated by claims about whether there is any syntactic structure at all at the elided position. For example, both Elbourne (2008) and Johnson (2001) suggest that normal syntactic structure (of the sort found in the antecedent clause) underlies the phonologically null (i.e., 'silent') elided position in the ellipsis clause (see also Lobeck 1995). Indeed, Johnson (2001) and others suggest that the entire VP from the ellipsis clause is displaced; at the minimum these accounts suggest that the two positions are 'syntactically related'. On the other hand, Hardt (1999, see also 1993) proposes that the relation between the elision clause and its antecedent is best expressed through a discourse model where the topic or 'center' of the initial clause is shifted in the second or ellipsis clause; there is no syntactic structure at the elided position and instead there is a pronoun-like element. Still others claim that VPE is best examined at the interface between a sentence grammar and a discourse model

(e.g., Lopez 2000; see also Williams 1977). Though it is not our intention in this paper to delve into, and test, the linguistic details of VPE, we initially assume that there is some syntactic structure in the elided position that requires reconstruction from the antecedent clause (see Shapiro and Hestvik 1995; see also Frazier and Clifton 2005 for arguments that syntactic structure is present at the ellipsis site).

Psycholinguistic evidence shows that interpretation of the VPE construction does not wait until then end of the sentence; it is accomplished as soon as the ellipsis is licensed. Namely, material from the antecedent is accessed immediately upon encountering the elision site (*did too*). As a recent example, Shapiro et al. (2003) presented sentences like the following to normal adult listeners:

2. The mailman bought a tie for Easter, and his brother, who was[1] playing volleyball, did[2] too, according to the sales clerk.

Using the cross-modal lexical priming (CMLP) task, lexical decision probes were visually presented at either the pre-elided position[1] or in the immediate temporal vicinity of the elision site.[2] The probes were related to either the subject NP (*the mailman*) or object NP (*a tie*) from the antecedent clause, or were unrelated control probes. Briefly, Shapiro et al. observed significant priming (faster RTs to related vs. control probes) for only the object NP, and only at the elided position (directly after the bare auxiliary *did*). This effect was interpreted as unambiguous evidence for the reactivation of the direct object DP (and not just any NP) from the first clause.

On the surface, this 're-activation' effect is similar to on-line gap-filling observed with complex object-relative constructions. Consider the sentence "*The police stopped the boy that the couple accused___ of the crime*." Here, the direct object of the verb '*accused*' is the NP *'the boy*', which has been displaced from its underlying and canonical position after the verb to a position prior to the verb. There have been a number of experimental investigations with unimpaired populations that have come to support the view that the linkage between an antecedent filler and a gap is one that is made immediately upon discovery of the 'gap' following the verb (e.g., Swinney et al. 1987; Love and Swinney 1996; Nagel et al. 1994). Though VPE is dissimilar to object-relatives (and wh-questions) because there is likely no displacement of any *individual* argument in VPE, still, interpretation relies on an antecedent, and there is reactivation of this antecedent at silent positions in both cases.

These facts bring us to aphasia; individuals with Broca's aphasia do not reliably understand sentences with displaced NPs, or perhaps more generally, sentences that require the computation of long-distance dependencies. Consider again an object-extracted relative clause (*The baker saw the boy who the girl kissed*) where the object NP (*the boy; who*) has been displaced from its post-verb canonical position. To be interpreted, such a sentence requires that the relativized NP (*the boy*) be linked to the relative clause verb (*kissed*) and be assigned the role of the recipient of the action. This reordering of NPs leaves a phonologically unrealized placeholder—called a trace—in the post-verbal position. This trace is linked to the displaced NP *the boy* so the role of theme—'the one being kissed'—can be assigned to the NP. Individuals with Broca's aphasia do not seem to understand these sentences, as observed

[1] The closest experiment to VPE in aphasia is reported by Vasic et al. (2006), who investigated the off-line ability of Dutch individuals with Broca's and Wernicke's aphasia to assign reference to pronouns. An examination of Vasic et al.'s materials indicates an absence of any elided category and thus their study did not probe VP-ellipsis. Their results, however, suggest that the disorder in Broca's aphasia does extend beyond an argument-displacement description.

[2] Two experimental studies were run. In one, two probe positions were investigated; in another, a separate position was investigated. The same procedures, participants, and materials were presented. Thus for simplification purposes, we present this as a single experiment.

in off-line sentence–picture matching and grammaticality judgment tasks (e.g., Caramazza and Zurif 1976; Friedmann and Shapiro 2003; Grodzinsky 2000; Grodzinsky and Finkel 1998; Grodzinsky et al. 1999; Love and Oster 2002).

Accounts of this putative syntactic comprehension deficit in Broca's aphasia differ on its source; one approach imputes comprehension deficits to the very feature of displacement: an inability to represent and/or interpret the co-referential dependency between the displaced phrase and its canonical position from which it arose is at the heart of the syntactic difficulties of individuals with Broca's aphasia (e.g., Zurif et al. 1993; Drai and Grodzinsky 2006; Friedmann and Shapiro 2003; Grodzinsky 1986, 1995; Hickok et al. 1993; Mauner et al. 1993). Even so, there may be a processing antecedent to this syntactic deficit, even if a linguistic description of the deficit pattern is necessary (see Grodzinsky 2000; Zurif 2000, for similar arguments).

Thus, a second approach takes syntactic deficits as reflective of processing limitations. Here, there are several kinds. One account implicates working memory (WM), based on the assumption that dependency relations of the sort evinced in object relative clauses, for example, require that the antecedent be maintained at least temporarily until the gap can be recognized. Note that there are several such WM accounts, running the gamut from a syntactically-specific WM (tied to constructions that require displacement; see Santi and Grodzinsky 2007) to a more general WM (e.g., Just and Carpenter 1992). There is also a recent account that suggests that in cases where processing load is high and resource availability is low, comprehension limitations will ensue (Caplan et al. 2007). One problem with this latter approach is that even sentences that are very short in length and require a minimal distance between filler and gap reveal comprehension deficits for individuals with Broca's aphasia (Friedmann and Shapiro 2003).

A related processing approach suggests that syntactic operations are time-sensitive and temporally unforgiving; computing a dependency relation must occur at the right time in the processing stream or comprehension will suffer. One such account suggests that syntactic structure formation is delayed in Broca's aphasia (e.g., Burkhardt et al. 2008; Haarmann and Kolk 1991); another suggests that lexical access is protracted, and that this limits the ability for individuals with Broca's aphasia to 'fill the gap' at the point where it is licensed in the syntax (Love et al. 2008; Swinney et al. 1996). These processing approaches require, then, tasks that are sensitive to the temporal evanescence of aurally presented sentences. Using such tasks, patients show antecedent reactivation in different types of movement-derived structures (unaccusative verbs, relative clauses, wh-questions)—may it be at a point later than its syntactic licensing (Burkhardt et al. 2003, 2008; Dickey et al. 2007; Dickey and Thompson 2004; Love et al. 2008; Swinney et al. 1996; Thompson and Choy in press; Zurif et al. 1993).

Hence, individuals with Broca's aphasia may lack the resources to adequately process sentences with displaced arguments in a timely fashion and/or to complete the comprehension process to yield a final and correct interpretation. Yet it remains unclear whether the source of these patients' difficulties lies in the reordering of phrases, in specific types of displacement, or in computing long-distance dependencies in general. Thus, investigations of ellipsis processing in aphasia could help resolve these issues, and this paper reports on our initial effort to do so.[1]

Current Study

With this brief background in mind we now present our initial investigation of VPE processing in aphasia. As described above, VPE is an excellent candidate to tease apart subprocesses involved in sentence comprehension. VPE appears to contain a silent placeholder

that receives its reference from an initial clause antecedent. In short, if antecedent reactivation is observed online in VPE and at the right point—in the immediate temporal vicinity where it is licensed (that is, at the elided position)—it will be the first study to show such reactivation in sentences that do not contain displacement of an individual NP. If so, then this pattern would be evidence that individuals with Broca's aphasia comprehended such constructions normally, and thus would also be partial support for a displacement-specific account of the syntactic deficits in Broca's aphasia. If we observe later-occurring effects (that is, some time after the elided position is encountered), then this would suggest that long-distance dependencies of different kinds are affected in Broca's aphasia, since such protracted effects have already been observed with other sentence types (e.g., Love et al. 2008). Finally, if we do not observe reactivation of the object within the elided VP in the ellipsis clause at any position, this would offer the first evidence of which we are aware that the deficit in Broca's aphasia extends significantly to constructions that contain more than a displaced NP. Perhaps VPE requires both syntactic reconstruction of a larger unit (a VP, rather than just an NP) as well as considerations of discourse and semantics, and these combine to overwhelm the processing system in aphasia. We return to this, and other, possibilities in our Discussion to follow our experiment.

Method

Participants

A group of nine stroke survivors (age at beginning of testing ranged from 45;11 to 84;0. Mean: 62.84) participated in the experiment. Each participant sustained damage to the left anterior cortex with sparing of the superior temporal gyrus/Wernicke's area following a single, MCA stroke. All participants were right-handed native English speakers with normal or corrected-to-normal visual and auditory acuity, and were at least 1 year post-onset. No participant had a previous history of other infarcts, alcohol/drug abuse, psychiatric illness or other brain disorder or dysfunction. The demographics for all participants are presented in Table 1.

Diagnoses were based on the convergence of clinical consensus and the results of standardized aphasia examinations including the Boston Diagnostic Examination (BDAE version 2; Goodglass and Kaplan 1972), the Boston Naming Test (Kaplan et al. 1983), and the Western Aphasia Battery (Kertesz 1982). Testing yielded a group of five individuals with Broca's aphasia and four individuals who presented with Anomia. The participants with Anomia served as a control group; these patients sustained damage to the LIFG but did not show the same behavioral patterns of impairment as our Broca's aphasic participants.

Materials and Design

We created 40 VPE test sentences, such as in (3).

3. The locksmith photographed the babysitter and the friendly[1] neighbor did[2] too, according to[3] the clumsy plumber. Sentence (3) contains an antecedent clause (*The locksmith*

[3] We also conducted an Omnibus three-way ANOVA with group as a between-subjects factor and probe position (all three positions) and probe type as within-subjects factors. We observed a main effect of group, $F2\,(1,32) = 137.755$, $p < .0001$, and a main effect of probe position, $F2\,(1.9,60.9) = 37.826$, $p < .0001$ (Greenhouse-Geisser corrected). We consider this three-way ANOVA to be an inappropriate method to examine our data given our hypotheses that the locus of any probe position effect or interaction will involve only two of the three probe positions, depending on the group factor. We conducted this ANOVA, however, simply to offer a complete set of analyses.

Table 1 Demographic information of participants in both Anomic and Broca's groups

Patient	Testing location	BDAE severity level[a]	Gender	Age (Y;M)	Post onset (Y;M)	Hemiparesis	Education	Lesion[b]
Broca group								
LT	SDSU	4	M	84; 0	3;1	R weakness	Bachelors	L ischemic event involving anterior MCA and including left caudate nucleus
ST	SDSU	1	F	55;11	10;11	R weakness	High School	L MCA embolic stroke; distribution encompasses broad left frontal lobe region
TL	DSU	3	M	52;7	7;7	R weakness	1.5 years college	Left parietofrontal CVA
TM	SDSU	3.5	M	68;1	1;8	R weakness	1 year college	Large left frontal lesion extending superiorly to the middle frontal region and involving the basal ganglia. Sparing of temporal and parietal lobes
WC	SDSU	2	M	45;11	5;5	R weakness	Bachelors, 1 year graduate school	Large area in left frontal cortical region including the basal ganglia and antero-medial portions of the temporal lobe and extending posteriorly to the parietal lobe
Anomic Group								
CE	UCSD	4	F	61;9	23;9	R weakness	2 years college	L basal ganglia, internal capsule, lenticular nucleus
FT	UCSD	4	M	68;2	11;11	None	8th grade	L IFG extending into the basal ganglia, internal capsule, lenticular nucleus
PY	SDSU	4	M	55;9	7;5	R weakness	3 years college	Large area of ischemia involving the L frontal cortical region & deeper structures in the basal ganglia
SH	UCSD	4	M	59;6	3;2	R weakness	Ph.D.	Infarction in left middle cerebral artery. Multiple areas of infarct: basal ganglia, corona radiate, optic radiations, internal capsule, and temporal cortex

[a] 1 = severe, 4 = mild

[b] *L* Left, *IFG* inferior frontal gyrus, *MCA* middle cerebral artery, *STS* superior temporal sulcus

photographed the babysitter) and an ellipsis clause (the *friendly neighbor did too, according…*). There is an elided VP in the second clause, signaled by the bare auxiliary *did*, which takes its reference from the antecedent VP (*photographed the babysitter*). All verbs were used transitively with direct objects that were living things (humans—as described by a profession—or animals). The number of syllables between the direct object (*babysitter*) and the elision site (*did too*) was kept constant at 5–7 syllables. Moreover, 'padding material' was inserted following the elison site to prevent end-of-sentence, wrap-up priming effects (Balogh et al. 1998). Finally, special attention was given to the sentences so that semantic relatedness of multiple noun phrases in each sentence as well as across neighboring sentences (i.e., two sentences presented one after the other) was avoided, to prevent indirect priming effects (see Appendix A for a full list of the experimental stimuli).

Eighty filler sentences were also generated. Thirty of these were elliptical constructions in which the overt direct object was a non-living object. The remaining, non-elliptical, fillers were either mono-clausal, coordinated, or relative constructions. Out of the 50 non-elliptical fillers, 20 occurred with an 'alive' direct object and 30 with a 'non-alive' direct object. In sum, across test and filler sentences, there were 70 elliptical sentences, 50 non-elliptical sentences, and direct objects were 'alive' exactly half of the time.

Ten novel multi-clausal sentences along with unrelated visual probes (half depicting "alive" entities) were added to form a practice block. Additionally, a total of 54 yes/no questions (4 for practice items, 20 for fillers, and 30 for test sentences) were generated to encourage participants to pay close attention to the sentence materials.

All sentences (including questions) were digitally recorded by a native speaker of English at an average rate of 4.34 syllables/s (within normal range). The recordings were then edited to delete silences at the beginning and ending of each sentence so as to keep the inter-stimulus interval constant. Recording and editing were performed using the Cool Edit Pro 1.2 software (Syntrillium Software Corporation).

We used a *Cross-Modal Picture Priming Paradigm* (Swinney and Prather 1989). In this dual-task, sentences were presented over headphones while participants were seated in front of a computer. At a given point during the unfolding of a sentence, a visual probe (a picture) appeared centrally on the screen for 1,500 ms. The participant's primary task was to listen to the sentences for comprehension. The second task was to make a semantic decision on the visual probes. Visual probes were sometimes related to a particular noun of interest in the sentence (e.g., an antecedent). Faster reaction times on related probes relative to control probes indicate a facilitatory or priming effect. A priming effect is interpreted as resulting from the activation of the noun of interest at that specific point in time.

In this study, the semantic decision (i.e., secondary task) was to determine whether the visual probes (pictures) were depicting living entities. Participants were encouraged to respond as quickly and accurately as possible by pressing the appropriate button (labeled 'Alive' or 'Non-Alive') on a 2-button box. Patients used their left hand for button press. The presentation software (Tempo, ver. 2.1.2) recorded reaction times and accuracy on the lexical decision task.

In our matched-sentence design, the same image was presented once with a test sentence to which it was related and again, in a separate session, with a test sentence to which it was unrelated. Thus, the visual probes served as their own controls. As shown in (3) above, three positions in the sentences were investigated. Probes were presented at a baseline, pre-elision site position (750 ms prior to the elided position); at the elided position; or at a post-elision site position (750 ms following the elision site). Hence, the complete design included six conditions: two probe types (related or control) and three probe positions (pre-elision, elision, post-elision sites). Half of the test sentences were assigned to the elision site, while the other

half were assigned to either the pre- or post-elision positions, depending on the experiment.[2] Participants contributed data to each condition yet saw each probe and heard each sentence only once per visit, thus avoiding within-session repetition.

In a given session, all 184 items (practice, test sentences, fillers and questions) were pseudo-randomized so that no more than three similar items or conditions would occur sequentially. Finally, participants were randomly assigned to an experiment/session; completion of the study required four experimental sessions, each visit approximately 2 weeks apart.

Procedure

Participants listened to sentences over headphones while seated in front of a computer. At a given point during the unfolding of a sentence, a picture probe appeared centrally on the screen. The participant was instructed to listen to the sentences for comprehension and to also make the semantic decision on the visual probes by pressing the appropriate button (labeled 'Alive' or 'Non-Alive') on a 2-button box. To encourage attention and effort in comprehending the sentences, participants were also informed that questions would be asked to verify comprehension.

Results

Prior to statistical analyses, incorrect responses (to the "live" decision, and failures to respond in the time allowed) were removed from further consideration; this yielded 3.95% of the data for the Anomic group and 1.16% of the data for the Broca group. Responses over 2,000 ms (Anomics = 2.95%; Broca's = 4.12%) were also removed from further consideration. Responses to the items "snail" and "babychicks" for the Broca group and "skier" for the Anomic group were removed from further analysis since the average responses for these items were over 2 SDs from the average RT for all items. Finally, outliers were defined, subject-by-subject, as those RTs for each condition that were over 2 SDs from the mean; these were replaced by the grand mean for each participant as a conservative measure. This data comb encompassed only 2.9% of the data for the Anomic group and 2.7% for the Broca group.

We conducted two separate mixed-design ANOVA's. The first was designed to examine the distinction between priming effects at the pre-elision and elision site positions, based on our apriori hypothesis detailed above. Recall that we predicted priming should only be observed at the elision site (and not at the pre-elision site), if in fact our Broca and/or Anomic groups reveal 'normal' reconstruction effects, based on Shapiro et al. (2003). Our second ANOVA examined priming effects at the elision and post-elision site positions, based on our hypotheses that individuals with Broca's aphasia will reveal protracted reconstruction (that is, at the post-and not elision site positions); as described above, this prediction is directly based on previous work suggesting a slow rise-time of syntactically-relevant processing routines.[3]

Our first mixed-design ANOVA, then, was conducted with group (Anomic, Broca) as a between-subjects factor, and probe position (pre-elision, elision site) and probe type (control and related) as within-subjects factors. An effect of probe type was observed; $F1\ (1, 7) = 4.545$, $p = .07$; $F2(1, 32) = 3.36$, $p < .07$. A main effect of Position was also observed, $F2(1, 32) = 39.5$, $p < .001$, as well as a significant three-way interaction among group, probe position, and probe type, $F1(1, 7) = 7.509$, $p < .05$; $F2(1, 32) = 5.286$, $p < .05$.

Table 2 Mean RTs (SDs) for the Anomic Group ($N = 4$) to probe type as a function of probe position

Probe type	Probe position Pre-elision	Elision	Post-elision
Control	908 (149)	1066 (346)	1075 (355)
Related	906 (162)	1005 (332)	1076 (358)
Priming effect[a]	2 ns	61* $p = 0.05$	−1 ns

[a] Statistical significance of priming effects indicated by * (significant) or by ns (nonsignificant)

We next conducted separate repeated measures ANOVAs (probe position: pre-elision, elision; probe type: control, related) for each group to search for the source of this interaction. We report on our analyses for the Anomic group first. We observed a significant main effect of probe position, $F2(1, 17) = 28.742$, $p < .001$, and probe type, $F2(1, 17) = 4.232$, $p = .05$ (no such main effects were observed on our F1 analysis). We also observed a significant interaction between probe position and probe type, $F1(1, 3) = 11.197$; $p < .05$; $F2(1, 17) = 7.223$, $p = .02$. Table 2 describes the data (subject-based; $F1$ analysis) for the Anomic group used in our analyses.

An examination of Table 2 the source of this interaction: at the pre-elision position, RTs to the related probes (906 ms) were not significantly different than those from the control probes (908 ms). However, at the elision site, RTs to related probes (1,005 ms) were faster by 61 ms than those to the control probes (1,066 ms), $t(3) = 2.20$, $p = .05$, one-tailed (subject-based data, collapsing across items); and $t(17) = 2.724$, $p < .01$, one-tailed (item-based data, collapsing across subjects).

For the Broca group, a main effect of probe type was observed, $F1(1,4) = 7.035$, $p < .06$. A main effect of probe position was also observed, $F2(1, 15) = 14.165$, $p < .01$. Table 3 describes the data for the Broca group used in our analyses.

An examination of the data in Table 3 reveals that at the pre-elision position, RTs to the related probes (1,067 ms) were faster by 48 ms than RTs to the control probes (1,115 ms), $t(4) = 3.465$, $p < .05$, one-tailed (subject-based data; no effect on item-based data was observed). No effects were observed at the elision site position, where RTs to related probes (1,210 ms) were not different than RTs to control probes (1,209 ms).

Our second mixed-design ANOVA was conducted with group (Anomic, Broca) as a between-subjects factor, and probe position (now, elision and post-elision sites) and probe type (control and related) as within-subjects factors. We observed a main effect of probe position, $F1(1, 7) = 5.316$, $p = .05$ and a main effect of group $F2(1, 32) = 67.684$, $p < 0.001$. We also observed a significant interaction between group and probe position, $F1(1, 7) = 7.399$, $p < .05$; $F2(1, 32) = 4.452$, $p < .05$.

To search for the source of these interactions, we next conducted two two-way repeated-measures ANOVAs, one for each group, with probe position (elision vs. post-elision sites)

Table 3 Mean RTs (SDs) for the Broca Group (N=5) to probe type as a function of probe position

[a] Statistical significance of priming effects indicated by * $p < 0.05$ (significant) or by ns (nonsignificant)

Probe type	Probe position Pre-elision	Elision	Post-elision
Control	1115 (134)	1209 (279)	1206 (276)
Related	1067 (128)	1210 (305)	1206 (313)
Priming effect[a]	48*	−1 ns	0 ns

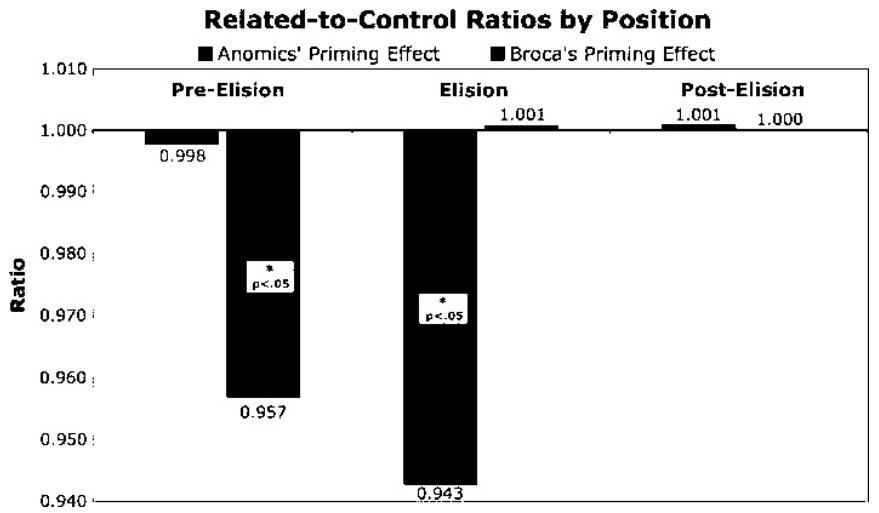

Fig. 1 Related-to-Control ratios for both groups as a function of probe position

and probe type (control, related) as within-subjects variables. The data from the Anomic group revealed a main effect of Position, $F1(1, 3) = 19.029$, $p < .05$; $F2(1, 17) = 5.956$, $p < .05$. A main effect of probe type was also observed on the $F2$ analysis only, $F2(1, 17) = 5.249$, $p < .05$. For the Broca group, no significant main effects or interactions were observed.

Finally, we analyzed the ratios of related RTs to control RTs. This procedure essentially 'standardizes' the RTs across groups and individuals, allowing baseline discrepancies between RTs to be eliminated. Priming (faster RTs to related compared to control probes) is obtained when the ratio is less than 1.0. Figure 1 describes the ratio data for both groups. For the Anomic group, we observed a ratio of .943 at the elided position, $t(3) = 2.304$, $p = .05$ (one-sample, one-tailed; subject data, collapsing across items); $t(17) = 2.474$, $p = .01$ (item-based data). For the Broca group, we observed a ratio of .957 at the pre-elision site, $t(4) = 3.317$, $p < .05$ (one-tailed; subject-based data only). No other ratios statistically differed from 1.0.

Discussion

In this experiment we investigated the processing of VPE in Broca's aphasia and in a group of brain-damaged control participants using a cross-modal comprehension task. To review, we aurally presented sentences like:

> *The locksmith photographed the babysitter, and the friendly*[1] *neighbor did*[2] *too, according to*[3] *the clumsy plumber.*

We presented visual probes either depicting the direct object NP from the antecedent clause (e.g., *babysitter*) or unrelated control probes, and these probes were presented at one of three probe positions: pre-elision, elision, or post-elision sites. With this task, faster RTs to probes

depicting the direct object, relative to RTs for the control probes, would indicate activation (priming) of the direct object NP.

The results indicated distinct priming patterns for the Broca group relative to the Anomic, brain-damage control group, as evinced by significant interactions involving the group variable. The Anomic group evinced no priming at the pre-elision position (or at the post-elision position); yet significant priming was observed at the elision site. Indeed, this effect was strong enough to yield a significant interaction between probe position (pre-elision, elision site) and probe type (related, unrelated probes). Furthermore, the ratios of control to related probes buttressed these effects; only at the elision site were the ratios significant. These patterns suggest that the participants with Anomia show normal reconstruction effects in VPE, similar to the healthy college-age participants tested in Shapiro and colleagues' work (Shapiro and Hestvik 1995; Shapiro et al. 2003).

Unlike the Anomic group, the Broca group evinced no priming or activation effect at the elided position; instead, a paired *t*-test on subject-based data only (collapsing across items) revealed a priming effect only at the pre-elision position. This effect was also captured on the ratio analysis, again with subject-based data only. Because the effect at the pre-elision site was not robust enough to capture analyses involving items, we hesitate to offer any strong conclusions. Even so, one possible interpretation for this early effect is spillover activation from the initial appearance of the direct object in the antecedent clause. The pre-elision site was located about 500 ms from the offset of the antecedent direct object, yet within the ellipsis clause. Late activation of overt noun phrases for these patients has been reported elsewhere (Love et al. 2008) and thus the results for this probe position partially support the hypothesis of a slower-than-normal lexical 'rise-time' deficit (Prather et al. 1991; Swinney et al. 1996) in individuals with Broca's aphasia and who have damage to Broca's region. Love et al. also reported that their Broca's participants eventually re-activated the antecedent to a displaced argument in object relative constructions ("The audience liked *the wrestler* that the parish priest condemned___ for foul language", where the NP *the wrestler* has been displaced from its canonical, post-verb position, leaving behind a trace or gap). Normal controls evinced reactivation of the antecedent right at the gap (immediately after, for example, the verb *condemned*) yet the post-gap position that evinced activation of the displaced argument for the Broca patients was 500 ms past the gap. These patterns suggested to Love et al. that the lexical processing deficit underlying Broca's aphasia percolates to the syntactic system, explaining some of the off-line comprehension problems such patients have with constructions that involve displacement of an argument.

Yet, unlike with object relative constructions, our Broca's aphasics could *not* link the VPE and its antecedent in real-time; again, we observed no activation effects even at the post-elision site. Even so, if syntactic structure must be built at the elided site as we have suggested in the Introduction, perhaps there is just not enough time for our Broca's patients to do this work. This possibility is directly related to accounts that claim that syntactic processing is delayed in Broca's aphasia (Burkhardt et al. 2008). A rather important caveat should be noted here. We observed *no* reactivation of the antecedent at the elided position or at the post-elision site.[4] Both the lexical rise-time and slow-syntax accounts rest on evidence of *eventual* reactivation effects, and thus we only have a null result to offer here as support.

[4] The absence of a priming effect at the downstream position is unlikely due to methodological shortcomings such as low statistical power (an effect was statistically obtained at the pre-elision site for these patients) or to problematic materials (the Anomic controls showed statistically reliable priming at the elided position, that is, the normal pattern). Furthermore, any limitations with the cross-modal technique (e.g., its dual-task nature) cannot explain the patterns here for at least two reasons: First, the Broca patients do show activation of the

We also suggested in the setup to our study that if we found no reactivation of the antecedent, then the deficit in Broca's aphasia extends to constructions that contain more than a displaced NP.

And this is indeed the pattern observed in our experiment. In VPE, the entire VP is the antecedent from which the elided position gets its reference. Perhaps the larger 'grain size' of the reconstructed constituent overwhelms the processing system in Broca's aphasia. Such a possibility would conflict with recent accounts of ellipsis processing in normal adults, where it has been claimed that antecedent (re)activation is cost-free (see for example, Frazier and Clifton 2001; Martin and McElree 2008; Arregui et al. 2006). Brain damage could, of course, modulate such a cost-free copy device. This possibility requires more work. We would need to first examine whether the lack of activation of the antecedent at or beyond the elided position percolates to off-line, final interpretation (as it does, for example, with relative clause constructions). We are currently conducting such an experiment.

Another possible explanation for the lack of activation effects at the elided or post-elision site may relate to the bare auxiliary that carries tense and agreement properties and that essentially signals that the clause in which it is contained is elliptical. Perhaps individuals with Broca's aphasia cannot process this unstressed 'closed-class' item in real time. There is of course a very large literature on comprehension deficits involving closed-class items (e.g., Bradley et al. 1980; Rosenberg et al. 1985; Swinney et al. 1980; etc.). One of the more recent attempts has found a real-time consequence of the vocabulary distinction in Broca's aphasia using event-related potentials (Keurs et al. 1999, 2002). This general account would require that the deficit extends to any structure that depends on the closed class vocabulary, and the evidence for this is at best equivocal, but requires further study.

We end with what we believe to be some important notes on patient classification. There is a likely distinct functional commitment of Broca's region versus, for example, classical Wernicke's area (see the discussion in, for example, Love et al. 2008; see also Caplan et al. 2007, for a different view). Yet, though all of our patients presented with neurological damage to LIFG, our Anomic patients evinced normal on-line VPE comprehension while our Broca patients did not. Though we have yet to examine whether the neurological damage between the groups can be differentiated with more detailed analysis (using, for example, probability maps of Broca's region; see Amunts et al. 1999), on the surface our results suggest that the coarse-grained neurology of the sort that defines left anterior cortex as the seat of syntactic comprehension deficits—or the locus of processing antecedents to these deficits—may not be the entire story. This conclusion might not be surprising, but it does complicate the relation between brain and language. This complication arises just because we have been careful enough to examine comprehension performance in constructions that are not, again, so easily divisible into classic psycholinguistic categories, and because we have used a brain-damage control group seldom used in the literature on Broca's aphasia. We conclude that this complication is a good thing and that it will eventually lead to a better understanding of language processing in both healthy and impaired populations.

Footnote 4 continued
antecedent, even if its only at the pre-elision site, and two, our brain-damaged Anomic control group evinced the exact patterns college-age normals did.

Appendix A

List of experimental sentences

1. The policeman carried the skier, and the helpful clown did too, according to the efficient waiter.
2. The kitten chased the chicken, and the beautiful girl did too, according to the short soccer player.
3. The elephant hit the ostrich, and the large orangutan did too, according to the busy cashier.
4. The fireman lifted the runner, and the professional dancer did too, according to the young geologist.
5. The nurse measured the Olympian, and the kindergarten teacher did too, according to the excited children.
6. The toddler caressed the gorilla, and the mayoral candidate did too, according to the injured producer.
7. The alligator devoured the lion, and the hungry piranhas did too, according to the loud spectators.
8. The puppy licked the toad, and the young pianist did too, according to the calm surgeon.
9. The eagle located the snail, and the chubby chipmunk did too, according to the agile climber.
10. The horse pulled the pig, and the stubborn rabbi did too, according to the anxious housekeeper.
11. The swimmer rescued the dog, and the eager tourist did too, according to the impressed teenager.
12. The water rafter quizzed the security guard, and the talk show host did too, according to the nervous farmer.
13. The mother massaged the auto mechanic, and the mad scientist did too, according to the new supervisor.
14. The fox bit the skunk, and the humongous snake did too, according to the shocked onlookers.
15. The ranger sketched the beekeeper, and the jazz musician did too, according to the self-conscious lifeguard.
16. The parrot watched the leopard, and the hairy tarantula did too, according to the bored bookkeeper.
17. The secretary applauded the dolphins, and the piano instructor did too, according to the precious footage.
18. The florist evicted a cheerleader, and the meter maid did too, according to the voted spokesperson.
19. The wolf dragged a reindeer, and the grizzly bear did too, according to the attentive guests.
20. The stewardess embraced the vet, and the excited reporter did too, according to the gracious gymnast.
21. The banker filmed the judge, and the history professor did too, according to the strong cyclist.
22. The counselor hugged the monkey, and the popular hairstylist did too, according to the strange teller.
23. The locksmith photographed the babysitter, and the friendly neighbor did too, according to the clumsy plumber.

24. The technician pushed the astronaut, and the angry sailor did too, according to the biased woman.
25. The girl scout lost a mouse, and the cocktail waitress did too, according to the brave bachelor.
26. The otter followed the lobster, and the funny architect did too, according to the smiling minister.
27. The hostess kissed the frog, and the desperate housewife did too, according to the talkative chef.
28. The actress pinched the gardener, and the sneaky carpenter did too, according to the brave roofer.
29. The rabbit scratched the grandmother, and the crotchety turtle did too, according to the puzzled visitor.
30. The bus driver bought an owl, and the lunch lady did too, according to the fancy art dealer.
31. The graphic designer fed the librarian, and the car dealer did too, according to the blonde stewardess.
32. The wrestler tranquilized the kangaroo, and the cowardly man did too, according to the bald optometrist.
33. The mailman scared the bodyguard, and the shady businessman did too, according to the gifted painter.
34. The taxi driver cued the baker, and the telephone operator did too, according to the tall officer.
35. The truck driver painted the electrician, and the hotel concierge did too, according to the lovely niece.
36. The goat kicked the donkey, and the cantankerous bull did too, according to the scared student.
37. The salesperson interrogated the hiker, and the female spectator did too, according to the pale model.
38. The manager shampooed the camel, and the massage therapist did too, according to the amused driver.
39. The actor washed the baby-chicks, and the famous singer did too, according to the tanned golf player.
40. The pelican passed the seal, and the blonde rapper did too, according to the prized writer.

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Chapter 4, in full, is an exact reprint of the material as it appears in Poirier, J., Shapiro, L. , Love, T. & Grodzinsky, Y. (2008). The Online Processing of Verb-Phrase Ellipsis in Aphasia. *Journal of Psycholinguistic Research*, 38(*3*), 237-253. The dissertation author was the primary investigator and author of this paper.

CHAPTER 5

Discussion

This dissertation investigated the real-time processing of ellipsis, with an emphasis on Verb-Phrase Ellipsis (VPE) and Sluicing. This work aimed to determine the meaning that is assigned to an ellipsis, and at what point in time the ellipsis is resolved. The results from three studies were reported: an investigation of VPE with unaccusative verbs (Chapter 2), an examination of the activation patterns in Sluicing (Chapter 3) and an evaluation of aphasic patients' online processing of VPE (Chapter 4). I begin by reviewing, chapter by chapter, each study's experimental findings and the conclusions that can be drawn from them. Next, I incorporate the contributions of this dissertation into the literature and revisit theoretical issues Ellipsis was utilized to investigate. Finally, I close with suggestions for future work.

Experimental Findings of this Dissertation

To begin, Chapter 2 aimed to determine whether traces are represented as silent reflexives by determining whether the sloppy and strict readings were computed for unaccusative verbs in VPE:

[1] [The dog]$_{NP1}$ disappeared $_{trace}$ in the crowded street fair and [the child]$_{NP2}$ with the blue jump①suit on did Ø ② too, much to the ③ family's dismay.

Sloppy reading: did too = disappeared $t_{the\ child}$

Strict reading: did too = disappeared $t_{the\ dog}$

Experiment 1 demonstrated that the sloppy reading was computed: the subject NP2 *child* was activated at *did too* with unaccusative verbs, but not with unergative verbs. For unergative verbs, an interference effect was observed at the downstream point from the elision site (③), such that NP2-related probes were responded to significantly slower than control probes. In Experiment 2, unaccusative and unergative verbs evinced identical patterns of activation: the subject NP1 was found activated starting at the earliest position (①) and until the elision site (②). This activation seemed to be unrelated to the presence of elided material since the activation began before the ellipsis was encountered. Hence, it could not be determined whether the strict reading is also computed for traces.

The findings from Chapter 2 shed light on several aspects of ellipsis resolution. First, only the syntactically-licit antecedent is recovered in the elliptical clause. For instance, subjects, which are generated external to the VP, are not re-activated at the elision site in VPE (unless co-indexed with an anaphoric object). Second, the patterns of results in Experiment 1 show a clear distinction between unergative (UE) and unaccusative verbs (UA). This experiment is thus the first to show that verbs are re-activated in ellipsis and further indicate that certain verbal properties (unergativity or unaccusativity) do affect parsing immediately. Third, an interference effect for the local subject (NP2) was observed at the downstream position with unergative verbs. This effect is difficult to interpret, but may reflect the re-activation of a covert verb's local arguments for integrative purposes. This hypothesis could reconcile conflicting results in the VPE literature regarding Subject reactivation (Koeneman, Bauuw, & Wijnen, 1998; Shapiro &

Hestvik, 1995; Shapiro, Hestvik, Lesan, & Garcia, 2003) and extend to non-elliptical structures, namely covert verbal anaphora. Fourth, the early activation patterns obtained for UA and UE verbs alike in Experiment 2 offer further support to the hypothesis that parallelism expectations induced by 'and' result in the activation of first-conjunct material soon after the conjunction is processed (Callahan, Shapiro, & Love, submitted).

Next, Chapter 3 investigated Sluicing, in which the antecedent is a clause (IP), to determine whether the entire antecedent would be recovered online:

[2] [The handyman threw a book to the programmer]$_{IP}$ but I don't know which book Ø ① and no one ② else seems to know.

The antecedent clause's Object (*programmer*) and Subject (*handyman*) were probed for in the elliptical clause. The Object was re-activated at the downstream position (at ②; no activation at ①). Surprisingly, Experiments 1A and 1B found no evidence for Subject re-activation, even in participants who demonstrated having processed the overt Subject in the antecedent clause and in participants who recovered the Object in the elliptical clause. Thus, only partial support for antecedent reconstruction could be obtained for Sluicing, but antecedent retrieval does seem to take place online, as the sentence unfolds.

This study is the first to attempt to determine whether an entire clause could be re-activated. As explained earlier and confirmed by the Chapter 2 study, syntactic

constraints limit reactivation to the syntactically-defined antecedent; until now, restrictions on how much of the antecedent must be included in the reconstruction had not been examined. The intriguing results from Chapter 3 suggest that there may be flexibility in ellipsis resolution so that antecedent may only be partially retrieved (perhaps due to an upper limit on the amount of material that can be recovered online) or may be reconstructed under a different form. This issue will be taken up in the next section. Still, the observation of Object reactivation indicates that the interpretation of Sluicing is computed online, before the sentence comes to an end. Finally, the timing of antecedent retrieval (i.e., Object re-activation) differs in Sluicing from VPE (Chapter 2); in the latter, but not the former, antecedent re-access was observed at the temporal position where the ellipsis was first encountered.

Lastly, Chapter 4 offered neuropsychological insights into the processing of Verb-Phrase Ellipsis (VPE). The ability of individuals with aphasia to re-access an antecedent that is more complex but does not putatively involve argument displacement was examined:

[3] The locksmith photographed the babysitter and the friendly ① neighbor did Ø ② too, according to ③ the clumsy plumber.

Patients with Anomia showed priming for *babysitter* at the elision site (②), suggesting they had retrieved the antecedent in a normal-like fashion. By contrast, patients with

Broca's aphasia did not show priming at the elision site or at the downstream point (③). This finding suggests that Broca's aphasia results in an inability to retrieve the antecedent in VPE, although individuals with Broca's aphasia do re-activate the antecedent (albeit late) in other types of constructions.

This study is the first to report distinct online behavioral patterns for Broca's aphasics and Anomic patients during sentence processing. Explanations for the comprehension problem in Broca's aphasia have included, among others, the inability to use closed-class vocabulary to parse the input (e.g., Bradley, Garrett, & Zurif, 1980), limited computational resources (Caplan, Waters, Dede, Michaud, & Reddy, 2007; Caplan et al.., 2007), deficits in activating lexical items at the right time during sentence comprehension (Love, Swinney, Walenski, & Zurif, 2008; Prather, Zurif, Love, & Brownell, 1997; Zurif, Swinney, Prather, Solomon, & Bushell, 1993), deficits in computing syntactic relations on-line (Burkhardt, Avrutin, Piñango, & Ruigendijk, 2008; Burkhardt, Pinango, & Wong, 2003), to the inability to appreciate displacement of arguments, which in turn results in problems with thematic role assignment (Grodzinsky, 1995, 2000; Hickok, Zurif, & Canseco-Gonzalez, 1993). Much of the evidence has suggested a role of the left Broca's region and/or anterior cortex in sentence processing.

Yet, the findings in Chapter 4 suggested that even though the left anterior cortex was involved in most of the patients categorized as either Broca or Anomics, they patterned differently on the online processing of verb-phrase ellipsis. In particular, Broca's aphasics failed to retrieve an antecedent altogether, although they do so (at a later

point than in neurologically-healthy controls) in constructions that involve displacement of an argument. This finding might indicate that the 'grain size' of the antecedent has processing consequences such that larger antecedents (e.g.: a VP in VPE) are more costly to re-access than smaller antecedents (e.g.: a noun phrase in movement constructions); patients' limited resources could be insufficient to retrieve a VP. Alternatively, Broca's aphasics could fail to detect the ellipsis, perhaps due to their difficulties processing closed-class words such as 'did' in did too or even the conjunction that signals the ellipsis clause. Clearly, if the presence of an ellipsis goes unnoticed, no antecedent reactivation would be expected. Hence, these neuropsychological data suggest that antecedent grain size or the ability to infer the existence of elided material play a role in the processing of ellipsis.

To summarize, the findings from Chapter 2 and Chapter 3 demonstrated that processing an ellipsis triggers the reactivation of material from the syntactically-defined antecedent phrase (a verb phrase in VPE and a clause in Sluicing). The results from Chapter 3 further suggest that although syntactic constraints restrict the selection of an antecedent (e.g.: subjects are not re-activated at the VPE), there may be flexibility in the way the processor reconstructs the interpretation at the ellipsis site. For instance, in Sluicing, a unit smaller than a clause could be recovered in the elliptical clause or the elided material could be reconstructed in a different syntactic form. The neuropsychological findings of Chapter 4 suggest that antecedent grain size could induce high processing costs and/or that patients fail to detect the elided constituent at its

temporal position without the overt cue '*did'*. With respect to time course, the findings of this dissertation suggest that ellipsis resolution may take place at different points in time, but is created in real time, during the unfolding of the sentence.

Comprehending Ellipsis

This section integrates the findings from this dissertation and the literature on ellipsis. Specifically, the experimental results of this dissertation are considered vis-à-vis two aspects of ellipsis processing: antecedent retrieval and ellipsis detection. I then revisit the theoretical issues that were investigated using Ellipsis as a research tool.

Recovering the meaning of the elided constituent

To comprehend an elliptical construction, comprehenders must fill in the 'missing' part of the sentence. The processing system constructs an interpretation for the silent phrase by referring to the first clause, from which it retrieves the meaning of the ellipsis. The present studies demonstrated that the elided constituent gets interpreted as a phonetically empty equivalent of the syntactically-defined antecedent. The mechanism by which the antecedent is identified, retrieved and assigned in ellipsis appears to be identical to that underlying the processing of other forms of anaphora, such as pronouns and traces (with perhaps one important exception, to be discussed below). Importantly, the present ellipsis investigations offer additional insights into the mechanisms involved

in the postulation of ellipsis and in the reconstruction of the antecedent in anaphoric relations. This dissertation thus extends the data upon which a comprehensive theory of anaphoric processing is to be elaborated.

With respect to recovering the meaning of an elided constituent, results from Chapter 3 confirmed that the grain size (i.e., categorical size) of the antecedent does not preclude its online reconstruction: evidence for antecedent reactivation was obtained in the elliptical clause (namely, priming for the Object of the clause). Unexpectedly, however, antecedent recovery appeared partial in this Sluicing study because the Subject of the antecedent clause failed to evince priming in the elliptical clause. This result was surprising for two reasons. First, previous research has repeatedly reported a lack of complexity effects in ellipsis interpretation (Frazier & Clifton, 2000, 2001, 2005; Martin & McElree, 2008). It was thus expected that the entire clause, despite its complexity, would be re-accessed, similarly to simpler antecedents. Second, the failure to retrieve the Subject could indicate that the selected antecedent is a phrase smaller than a clause − the syntactically-defined antecedent in Sluicing. Sluicing would be, in this case, the only anaphor studied thus far to assign an antecedent that does not match the referent-seeking element on phrasal category (verb, noun phrase, verb phrase, clause, etc.). I turn to each issue separately.

With respect to complexity effects, the definition of complexity might need to be revisited. For example, there are two factors that do not increase processing loads, but that negatively affect ellipsis interpretation: distance and number of referential noun

phrases (NPs). Speed-accuracy trade-off studies have reported a slight decrease in accuracy levels with higher numbers of (NPs) in the antecedent and with more distance antecedents (Martin & McElree, 2008). These effects could be due to increased interference during antecedent retrieval, as more material intervenes between the antecedent and the ellipsis in these cases. Furthermore, a memory-based parsing model of sentence comprehension has proposed that processing difficulty results from the difficulty in retrieving phrases from memory (Lewis, Vasishth, & Van Dyke, 2006). Hence, the patterns of activations observed in Sluicing could be attributed to a complexity effect defined in terms of inference during memory retrieval.

In effect, the antecedent in Sluicing would create greater interference due to the higher number of NPs in a clause compared to other antecedents (such as verb phrases in Verb-Phrase Ellipsis). Moreover, interference would differentially affect the Subject and the Object in Sluicing: the Subject is farther from the ellipsis and thus potentially subject to more interference than the Object. In this way, the processor would fail to retrieve the Subject in Sluicing due to interference. However, the memory-based model referred to above associates processing costs to interference that should be detectable in reaction times; still, distance and number of referential NPs did not affect processing speed (Martin & McElree, 2008). Additionally, these factors should also apply to non-clausal antecedents. That is, antecedents such as verb phrases with a similarly high number of NPs and that are more distant from the ellipsis (i.e., long antecedents) would be expected to show processing difficulty (due to interference). Yet, such long non-clausal antecedents

(verb phrases in VPE) are not processed differently from shorter antecedents (Martin & McElree, 2008, Exp. 4). It thus seems unlikely that interference alone could explain the lack of Subject re-activation, since an antecedent with similar properties (length and number of NPs) did not affect accuracy – or speed – of retrieval in VPE. In short, interference as an index of complexity does not straightforwardly account for the pattern of results observed in Chapter 4.

There is another aspect of the antecedent in Sluicing that could make it more costly to process. Thus far, the definition of complexity has assumed that grain size (categorical identity) and amount of material (number of phrases in the antecedent) are interchangeable. This assumption may be incorrect, particularly in light of the failure to retrieve the Subject. For instance, previous work in which complexity effects were sought manipulated complexity within a phrasal category (simpler vs. more complex VPs in VPE). The increase in syntactic complexity between a simple verb (in gapping) up to a full clause (in Sluicing) has never been directly examined. A clause clearly involves more syntactic structure than a verb or a verb phrase; to rebuild a clause, the parser would have to build all the nodes of the syntactic tree and/or retrieve information from the lower lexical heads up to the higher inflectional nodes. In contrast, reconstructing a smaller phrase only involves the lower lexical nodes of the tree:

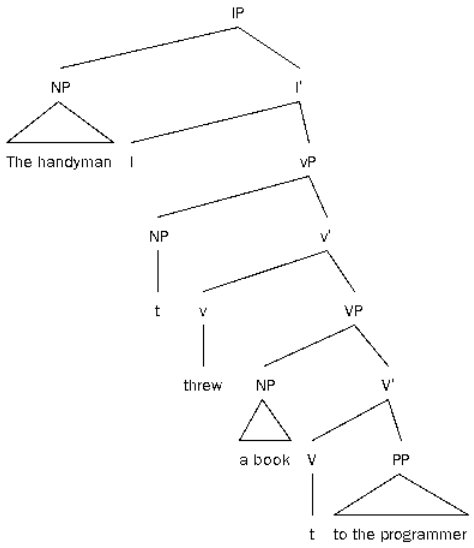

Figure 5.1 Syntactic tree for antecedent clause in Sluicing



Figure 5.2 Syntactic tree for antecedent verb phrase in VPE

In Sluicing, part of the antecedent is high in the tree, in the inflectional nodes. This element, the subject *the handyman*, is not re-accessed in the elliptical clause. In VPE, the antecedent lives at the bottom of the tree, in the lexical nodes; it can thus be retrieved without accessing the higher, inflectional nodes. Thus, it is possible that reconstructing a clause is more complex and costly due to the need to retrieve information from the inflectional nodes (e.g., above vP). In fact, a similar processing cost

for inflectional nodes has been proposed in aphasia to account for patients' agrammatic production, which is limited to lexical nodes (Friedmann, 2006; Friedmann & Grodzinsky, 1997).

This hypothesis could be tested in Sluiced sentences with a passive antecedent:

[4] [A book was thrown to the programmer [by the handyman]$_{Subject}$]$_{IP}$, but I don't know why.

If 'grain size' matters such that in antecedents with a high number of nodes, the external argument (Subject) is left out, the Subject *handyman* should be left out to reduce processing costs. If, rather, the difficulty stems from accessing noun phrases in the higher inflectional nodes in the syntactic tree, the lower-situated Subject should be easily retrieved. The reverse pattern would be expected for *book*: the noun phrase would only reactivate if Subjects are dropped in Sluicing due to the high number of nodes to rebuild, and would not be retrieved if accessing material in inflectional nodes is too costly. This experiment could also be carried in a language that allows the Object-Verb-Subject order, in which the Object appears high in the tree and the Subject, at its foot. Such a language that also permits Sluicing constructions is Italian. Thus, cross-linguistic data could inform on the language-universal and language-specific constraints implicated in Sluicing and Ellipsis in general.

The alternative view of complexity, defined in terms of number of phrases in the antecedent, has not found experimental support in previous work. That is, longer antecedents are not associated with higher processing loads (as reflected in reaction times in reading and speed-accuracy trade-off paradigms). Because the conclusion that antecedent complexity does not affect antecedent retrieval is based on a null result (absence of slower reaction times with more complex antecedents), it is also possible that there are indeed complexity effects, but that they have thus far been missed. In fact, the effect of antecedent complexity has only been studied in the written modality (in self-paced reading, speed-accuracy trade-off and eye-tracking paradigms) and in stimuli where the ellipsis is sentence-final (Frazier & Clifton, 1998, 2001; Martin & McElree, 2008). The unnatural presentation of stimuli in these studies (phrase-by-phrase) may have led participants to process the stimuli differently than normal, for example by inciting participants to chunk the material. Also, these studies used stimuli in which the ellipsis occurred sentence-finally. Considering that end-of-sentence wrap-up effects have been shown to trigger reactivation of previously encountered material (Balogh, Zurif, Prather, Swinney, & Finkel, 1998), it is possible that processing costs incurred by the antecedent retrieval operation could have been masked by ellipsis-unrelated, wrap-up activation processes. In short, methodological considerations might have contributed in the failure to find complexity effects in the literature. If such effects do exist, they might explain the absence of the Subject in the Chapter 3 study (Sluicing), assuming a clause is too costly to be recovered in real time.

The incomplete reconstruction of the antecedent in Sluicing was puzzling for another reason: Sluicing would be the only instance of an antecedent differing in phrasal category from the antecedent-seeking element. This apparent anomaly could be reconciled with the anaphora literature if the reactivation observed in Sluicing (Chapter 3) is assumed to indeed be that of a clause (IP), but of a passive IP. The focus on the remnant object (*which book*) foregrounds the phrase as the probable topic of the upcoming clause; the passive voice would realize that expectation by making the remnant the subject (topic) of the sluiced sentence.[1] The subject of the antecedent clause could then be dropped from the passively reconstructed sluiced sentence (*which book was thrown to the programmer*), explaining the lack of subject re-activation. Thus, Sluicing would behave like other types of ellipsis and anaphora and be assigned an antecedent that match the elided element on categorical identity (i.e., an IP).

Although the experiments reported in this dissertation were not specifically designed to test the presence of syntactic structure at the ellipses, their results can be considered vis-à-vis the theoretical approaches to ellipsis interpretation. The current data do not clearly support a view that claims syntactic structure exists at the elision site (syntactic accounts) or approaches that refute its presence (semantic- or discourse- based accounts). In effect, there is no unequivocal reason why the reconstruction at the ellipsis excludes the subject of the antecedent in Sluicing. In semantics approaches, for instance, the pronoun-like element that is postulated at the elision site should refer to their

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[1] Syntactic accounts do allow syntactic mismatches (e.g., active antecedent and passive elided structure), modulo additional processing costs (Arregui, Clifton, Frazier & Moulton, 2006; Frazier & Clifton, 2005).

syntactically-defined antecedents just as pronouns do. (Similarly, the psycholinguistic account implicating a memory pointer in ellipsis (Martin & McElree, 2008) would predict the re-access of the mnemonic representation of the full antecedent.) Syntactic accounts fare slightly better, assuming one of the three possibilities discussed above for Sluicing is correct (complexity involving inflectional nodes, complexity as the number of syntactic nodes, or reconstruction in the passive voice). Note that these hypotheses all *entail* that there be syntactic structure at the ellipsis.

The notion of reconstruction of syntactic structure in accordance with the local context (i.e., in the passive voice) fits well with the view that parsing does not result in the building of a stable, full-fledged syntactic structure of a complete sentence but is a collection of locally-computed interpretations (the 'Good-Enough' Approach; Ferreira et al., 2002; Ferreira & Patson, 2007). In fact, locally-computed interpretations can even interfere with global ones (the final, integrated interpretation of the sentence). In this framework, the reconstruction of the sluiced clause would reflect the local constraints; eventually, a global interpretation for the whole sentence would be constructed and may re-integrate the subject of the antecedent clause. In any case, accounts postulating syntactic structure at the ellipsis seem more apt to explain the absence of the subject in the elliptical clause.

This proposed interpretation of the Chapter 3 (Sluicing) findings is speculative, but consistent with a growing literature on the role of focus in ellipsis resolution (Carlson, 2002; Frazier, Clifton & Carlson, 2007; Kertz, 2008; Carlson, Dickey, Frazier

& Clifton, 2009). Interestingly, this hypothesis proposes a new role in comprehension for focus beyond the functions of identifying new/given information and guiding selection between alternatives during ambiguity resolution. Namely, focus may induce structural preferences or expectations that the processing system would favor when parsing the input.

Detecting the implicit phrase

The study of ellipsis also permits the examination of the processes underlying the postulation of an implicit anaphor. Research on the topic has thus far focused on wh-traces (as in *The policeman talked to the boy who the crowd accused _t_ of the crime*). This form of implicit anaphora is overtly signaled by the pronoun 'who'; the processor, upon hearing 'who', recognizes the indication of the upcoming implicit anaphor and begins searching for the location of the wh-trace (Frazier & Flores D'Arcais, 1989).[2] Thus, a wh-trace is predicted from the overt cue and not postulated after the absence of *boy* in the postverbal position is noticed. In ellipsis, by contrast, no overt cue alerts to the upcoming implicit anaphor. Consequently, the processor postulates an ellipsis after a structure violation is detected in the elliptical clause – a post hoc operation to handle the problem of a missing phrase. [3]

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[2] In fact, in constructions without the optional overt cue 'who', wh-traces are postulated after a delay (Swinney & Osterhout, 1989).

[3] This proposed dissociation in mechanisms is supported by neurophysiological evidence on gapping. In effect, Kaan, Wijnen & Swaab (2004) interpret their findings as indicating that ellipsis and wh-movement involves different processes.

Hence, ellipsis can help shed light on how the processing system goes about detecting or positing implicit components when no overt signal is available. The work presented in this dissertation suggests that the processing system benefits from a general mechanism in resolving ellipsis. Namely, the expectation of parallelism in 'and'-conjoined constructions, a phenomenon applying to nonelliptical structures as well, seems to facilitate ellipsis resolution. In the absence of parallelism expectations, antecedent reactivation does not occur at the temporal location of the ellipsis but rather takes place at a later point (Chapter 3; see also Shapiro & Hestvik, 1995, Exp.2). In the presence of parallelism expectations, the antecedent is activated at (or near) the temporal position of the ellipsis (Chapter 2). Earlier ellipsis resolution is thus observed in 'and'-conjoined sentences.

Taken together and combined with the literature on ellipsis, the present findings suggest that the comprehension system can potentially interpret an incomplete input via two routes. 1) by rendering accessible material from the first clause that can immediately fill a 'gap' and/or predict the structure of the second clause; and 2) by inferring the existence of an ellipsis based on context and triggering a search for an antecedent. The first mechanism is associated with sentences in which parallelism is expected (in non-elliptical and elliptical constructions alike). The proposed function of parallelism expectations in ellipsis resolution (see also Callahan, Shapiro & Love, submitted) is consistent with models that attribute a role to probabilistics and predictability in processing (e.g.: Levy, 2008). This novel relation between ellipsis and parallelism

expectations highlights the variety of mechanisms and heuristics the comprehension system draws upon to efficiently process a rapid and complex input.

The second mechanism specifically involves the postulation and interpretation of an ellipsis (or of implicit anaphora that appear without an overt cue). This mechanism posits an implicit anaphor as soon as the processor detects a phrase structure violation. Immediately thereafter, an antecedent search is launched and the antecedent is integrated into the sentential context. In this case, the processor did not anticipate any structure, by contrast with 'and'-coordinated sentences. It rather *reacts* to the realization that the input is incomplete and by deduction, includes an implicit constituent. Consequently, the resolution of the ellipsis is only observable at a later point in time, after the phrase structure violation has been confirmed.[4]

The distinction in mechanisms involved in ellipsis resolution should be kept in mind when investigating ellipsis *per se*, especially in coordinated sentences. In effect, the processes under study may be general operations of the comprehension system and not ellipsis-specific. Importantly, the observation of two separate mechanisms can reconcile inconsistent findings in the literature regarding the time course of ellipsis resolution. It further situates ellipsis within the framework of general language processing and enriches

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[4] Thus far, these later effects have only been observed 500-600ms post ellipsis (Shapiro & Hestvik, 1995, Exp. 2 and Chapter 3 of this dissertation). However, it is possible that ellipsis be detected earlier than that. In effect, phrase structure violations are typically detected some 100-300ms after the onset of the word violating phrase structure (based on neurophysiological data; see Friederici, 2002 for a neurocognitive model of language processing). The elided phrase would be inferred and interpreted shortly thereafter. Thus, ellipsis may well be resolved between the elision site and the 500-600ms position.

our understanding of how the comprehension system attributes meaning to silent sentential elements.

Ellipsis as a Research Tool

As explained in the Introduction (Chapter 1), ellipsis was utilized in this dissertation to test specific hypotheses about the representation and processing of language (Chapters 2 and 4). In this section, the results of the studies in Chapters 2 and 4 are re-visited from a new perspective. The goal is to bring some of the insights on ellipsis gained from this dissertation to evaluate the implications of these experimental results for the theoretical questions (ellipsis-unrelated) these studies aimed to test.

In Chapter 2, Verb-Phrase Ellipsis provided a vehicle to tap into the mental representation of traces. As a reminder, a trace was inserted as the object of the antecedent verb phrase (VP). It was hypothesized that a trace, if represented as a phonetically unrealized reflexive, would trigger the re-activation of the antecedent clause's subject in the elliptical clause. This hypothesis could not be verified because an expectation of parallelism was created by the conjunction 'and' and the subject was reactivated before the ellipsis was processed. In light of the role of coordination on activation patterns this dissertation has documented, it would be desirable to reproduce Experiment 2 of Chapter 2 in non 'and'-coordinated sentences. The choice of a conjunction that does not induce expectations of parallelism (such as 'but'; see

Knoeferle, 2007) would prevent the early and confounding activation of the subject in the second conjunct. The observation (or not) of a priming effect in the elliptical clause could then be interpreted vis-à-vis the theoretical issue the experiment was designed to address.

The role of parallelism resurfaces in the re-evaluation of the findings from Chapter 4. In this study, Verb-Phrase Ellipsis served the examination of the processing of an anaphoric relation that does not involve argument displacement in aphasic patients. Patients with Broca's aphasia did not seem to even detect the ellipsis (no priming for the antecedent was obtained in the elliptical clause), in contrast with their protracted but successful resolution of other anaphoric relations (e.g., wh-traces).

Two new explanations for the surprising finding can now be offered. First, patients may not have processed the conjunction 'and', which would prevent them from expecting a parallel clause. As mentioned in the Chapter 4 discussion, patients' difficulties with closed-class words (such as 'and') are well documented and seem to extend to online processes. It has been suggested, for instance, that patients can no longer use closed-class words to support the construction of phrase structure (Bradley et al., 1980; Shapiro & Jensen, 1986). It is thus possible that patients fail to process the conjunction or that the conjunction fails to induce an expectation of parallelism, at least in real time. As a result, no material from the first clause would have been available in the second clause when the ellipsis was encountered and no specific syntactic structure would have been expected in the elliptical clause.

Hence, Broca's aphasics appear to be deprived of both mechanisms (expectation of parallelism or detection of a phrase structure violation) to resolve an ellipsis. Indeed, assuming that the parallelism-induced reactivation mechanism was unavailable to patients, the ellipsis should have been inferred from the context in the second clause. This process of inference begins with the detection of a word-category violation, which patients reportedly cannot accomplish in real time (Wassenaar & Hagoort, 2005).[5] Hence, patients' inability to interpret the ellipsis would stem from a double deficit that precludes the successful application of either ellipsis-resolution mechanism.

Future Directions

The contributions of this dissertation shed light on the interplay of prior context (parallelism expectations), structural constraints (categorical identity of elided material) and perhaps even information structure (focus) on the processing of ellipsis. The intersection of any of these factors will certainly prove to be a fruitful area to explore experimentally in the future, starting with the replication and clarification of the findings in this dissertation. In the next paragraphs, I offer suggestions of topics and studies that would theoretically pick up where this dissertation leaves off.

In Chapter 2, it was suggested that covert verbs may require additional processing compared to covert noun phrases or overt verbs. Specifically, it was proposed that a

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[5] Incidentally, Broca's aphasics show more important deficits in processing closed-class words than Anomics (Smith & Bates, 1987). Anomics may thus be able to detect the phrase-structure violation and infer the implicit anaphor and/or make use of parallelism expectations.

covert verb needs to re-access its arguments during the postverbal segment to fully integrate the recovered verb into the sentential context. This hypothesis was formulated based on reading times, speed-accuracy trade-off, neurophysiological and phrase activation evidence. It will be important to experimentally confirm the observation-based hypothesis and to investigate its underpinnings.

Next, the comparison between the processing of wh-traces and ellipsis emphasized the critical role of overt cues in the time course of covert anaphor resolution. Other types of cues have thus far been understudied in ellipsis: the presence of overt 'remnants' that unambiguously signal the location of a phrase as well as sentential prosody. For instance:

[5] The farmer worked all afternoon and the fisherman did Ø too.

[6] The activist likes original dishes and the accountant, Ø traditional ones.

In the verb-phrase ellipsis example in [5], the auxiliary *did* unambiguously indicates that the next phrase will or should be a verb phrase. By contrast, in the gapping example in [6], no clear indication is given as to how the parse will continue. Indeed, the segment after *accountant* could be a prepositional phrase (*with the large glasses*), a verb (in a nonelliptical sentence: *the accountant couldn't agree more*) or a noun phrase (as in gapping). In [6], the parser may need to process more input to determine which possible

continuation is the correct one.[6] Thus, the parser may be able to posit the ellipsis earlier in [5] because only one continuation is allowed and a violation of that restriction would be quick to detect.

To conclude, the real-time resolution of ellipsis was argued to implicate syntactic constraints, expectation-based heuristics and information structure influences. Experimental evidence is converging to show that the processing system makes use of many sources of information to optimize its efficiency in parsing the input. Ellipsis is no exception. This dissertation has offered several insights into the comprehension of elliptical sentences but also unveiled potential factors that have thus far been overlooked or understudied. Certainly, ellipsis provides an excellent research tool to examine the interplay of syntax, lexical properties and prosody, and the role of prior experience and immediate context… among others.

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[6] Note that the amount of input required ascertaining the existence of the ellipsis is intricately related to the neighborhood density of the next word, or how quickly the processor can establish the identity and phrasal category (noun, verb, etc.) of the word. For instance, the word *too* in this VPE construction [1] lasts ~150ms. Its category (preposition) is confirmed much more quickly than a longer word with multiple neighbors can be securely identified.

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