Recursion in Nicaraguan Sign Language

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Abstract

Syntactic recursion is argued to be a key property of natural languages, allowing us to create an infinite number of utterances from a finite number of words and rules. Some have argued that recursion is *uniquely* human. There are at least two possibilities for the origins of recursion: 1) Recursion is a property of the language faculty. 2) Recursion is an historical accomplishment and is culturally constructed over millennia. Here we ask whether an emerging sign language, Nicaraguan Sign Language (NSL), exhibits syntactic recursion by comparing the language of the first three age cohorts of signers. Signers (n=27) watched and described vignettes designed to elicit relative clauses. Results suggest that signers from all three cohorts have strategies to fulfill the discourse function of relative clauses, picking out an individual from a set. The grammatical form of the utterances differs across cohorts, with signers from later cohorts clearly producing embedded structures.

Keywords: language emergence; syntactic recursion

Introduction

Recursion, defined as "a procedure that calls itself, or… a constituent that contains a constituent of the same kind" (Pinker & Jackendoff, 2005), is argued to be a key property of natural languages, allowing us to create an infinite number of utterances from a finite number of words and rules[1]. For instance, we can generate sentences like "Sally said that the boy cried" from "The boy cried," and "Billy thinks that Sally said that the boy cried" from "Sally said that the boy cried," and so on. Some theorists have argued that recursion is *uniquely* human and might even be the sole property that sets human language apart from animal communication systems (Hauser, Chomsky, Fitch, 2002). However, at least one language, Pirahã, has been reported to lack syntactic recursion (Everett, 2005), raising doubts about this claim. It remains an open question as to whether recursion is indeed a hallmark of human language and if so, where the capacity to implement rules within rules comes from.[2]

A central goal in cognitive science has been the identification of what uniquely human properties account for our language system. One possibility is that language arises from our mental architecture, and the capacity to create language is present is every human mind. The language faculty may be a part of our genetic endowment (e.g., Chomsky, 1968; 2000; Pinker, 1994) or language may be a product of general changes in our conceptual resources and computational abilities (e.g., Christiansen & Charter, 2008). The properties and organization of language then reflect the structure of human cognition (Chomsky, 1975; Pinker, 2007). A second possibility is that language developed gradually over historical time, rather than phylogenetic time, through a process of "cumulative cultural evolution" (Tomasello, 2011; Tomasello, Kruger, & Ratner, 1993). Here, language is a side effect of the human capacity for social learning and cultural transmission (e.g., Tomasello, 2008).

Recently, the study of emerging sign languages, such as Nicaraguan Sign Language (NSL), has offered the opportunity to better understand how languages are created and the roles of the individual learner and the community of users. NSL is a new language created by a deaf community in Managua, Nicaragua. Before the 1970s, there was little opportunity for deaf people to gather together and interact, and consequently Nicaragua had no standardized sign language. In the mid-1970s and early 1980s, the government opened a new primary school for special education followed by a vocational school. For the first time, deaf Nicaraguan children and adolescents were able to gather together in large numbers. While lessons were in spoken Spanish and instruction primarily focused on lip-reading and speaking Spanish (with limited success), students communicated through gestures, and a new sign language emerged and continues to develop (Polich, 2005). Each successive group of children who enters the community introduces linguistic complexity into the language that adults are unable to acquire (Senghas, 1995; Senghas & Coppola, 2001). This pattern gives rise to a unique community, where the older signers, the initial creators of the language, represent earlier stages of the language than do younger signers (Senghas, Kita, & Özyürek, 2004). Today, NSL has multiple co-existing age cohorts of users, from the creators of the language to the young children now learning and changing the language. In this project, we examine the language of signers from the *first cohort* (children who entered the community in the 1970s and early 1980s, the *second cohort* (entered the community in the mid-1980s to early 1990s),

[1] Note that recursion is not unique to the language system. Recursion is a property of generative systems and is found in other cognitive domains, such as visual cognition.

[2] There is a great deal of controversy about recursion, its definition, and its relevance to language and types of output generated by recursive functions (e.g., Tomalin, 2006; Watumull et al., 2014). In this paper, we adopt one definition, used by Pinker & Jackendoff (2005) and others: the embedding of a constituent in another constituent of the same type.

and the *third cohort* (entered the community in the mid-1990s to early 2000s).

By comparing the language of different cohorts of children who entered the community at different times, research on NSL to date has revealed a rich and nuanced picture of how historical and cognitive processes interact (e.g., Flaherty & Senghas, 2011; Pyers et al., 2010; Senghas, 2003). Many features of language do not develop immediately from the structure of a single human mind, nor do they require long periods of historical evolution. Instead, these elements emerge over the span of a few generations, indicating that convergence on these forms does not require prolonged historical evolution, but may require a community of users, transmission, and in some domains, sequential age cohorts of learners.

The present study addresses a fundamental unanswered question about a key property of language and the human mind. Specifically, we explore when recursion emerges in the creation of a new language.

The capacity for, and importance of, recursion in the language system can be seen in children's acquisition of syntactic recursion. Languages vary in which structures are recursive. For instance, possessives are recursive in English, but not in German (Roeper, 2011). This cross-linguistic variability in syntactic recursion has been argued to pose a learning challenge for children acquiring their first language (Roeper, 2011). Nonetheless, children can and do acquire syntactic recursion. Preschool-aged children are initially less likely to assign a recursive interpretation to embedded structures, parsing them as conjoined instead. For instance, when presented with an array of five balls in the order of red, green, blue, orange, and green, and asked to show the experimenter "the second green ball," 3- and 4-year-olds chose the first green ball in the array rather than the second (Matthei, 1982). Similarly, other work demonstrates that young children initially prefer conjoined interpretation for possessives in English and Japanese and then acquire the embedded structure (Fujimuri, 2010 as cited in Roeper, 2011; Limbach & Adone, 2010).

Everett (2005) argues that Pirahã lacked syntactic recursion. Further experimental work was not successful in eliciting embedded possessives or relative clauses in elicitation tasks (Piantadosi et al., 2012). In addition, a corpus analysis based on 15 stories (approximately 10,000 sentences) revealed no strong evidence of recursion for relative clauses, complement clauses, possessives, or conjunctions and disjunctions, but there was possible evidence suggesting recursive use of topics or repeated arguments (Piantadosi et al., 2012). The question of whether or not Pirahã lacks syntactic recursion remains open (e.g., Nevins, Pesetsky, & Rodrigues, 2009).

In the current study, we turn to an emerging language and ask whether NSL exhibits syntactic recursion and if the cohorts of signers show differences in the types of structures they produce. There are at least three broad possibilities for the origins of recursion. The first is that recursion is a property of the language faculty and thus should emerge early in a new language, like NSL (and Pirahã is anomalous, but see Piantadosi et al., 2012). The second is that recursion is an historical accomplishment (like mathematics) and is culturally constructed over time (e.g., Deutscher, 2005; Tomasello, 1999; 2008; 2011). On this view, recursion should not emerge in just three generations of NSL signers. A third possibility is that recursion is a property of the human mind, but a new language takes time to converge on (syntactic) forms for its expression, perhaps because of the need for a community of users.

Certain linguistic structures have been identified as typical examples of recursion, such as adjectives (*the second green ball*), relative clauses (*the boy who kicked the ball fell down*), complements (*John thinks that Sally is not coming today*), possessives (*my mother's brother's daughter's dog*), and prepositional phrases (*the cat in the hat on the table*) (Everett, 2010; Roeper, 2011). We investigate one structure that can take recursive interpretations: relative clauses. Comparing the language of three age cohorts of NSL signers, we ask how early we might observe evidence for syntactic recursion to better understand where the capacity for recursion stems from and when it emerges in a new language.

Experiment 1

Relative clauses serve to pick out an individual or subset from a set of referents (e.g., *the boy who was typing* from a set of boys performing different actions). Syntactically, relative clauses are full clauses that modify a noun phrase. In many languages, they contain a gap: a missing argument that is co-referential with the noun that they modify. In other languages, or syntactic contexts, this gap is filled, for example, with a resumptive pronoun as in "There are guests who I am curious about what *they* are going to say" (Prince, 1990). Semantically, they contain an element that is related to the noun or noun phrase. In the experiment, we examine whether NSL signers have strategies to fulfill the discourse function of relative clauses, namely picking out an individual from a set and whether there are form-based distinctions in the syntax.

Method

Participants in this study were 27 deaf Nicaraguan signers who were exposed to the emerging sign language by 6 years of age. Ten of the participants entered the signing community before 1983 (mean age of entry: 3.99, range: 3.0-5.7), and are referred to as the *first cohort* (mean age: 41.69, range: 37.2-46.8). Ten participants entered the community between 1986 and 1990 (mean age of entry: 4.01, range: 3.1-5.3), and are referred to as the *second cohort* (mean age: 30.84, range: 28.2-33.4). Seven participants entered the community between 1993 and 1998 (mean age of entry: 3.77, range: 3.0-4.6), and are referred to the *third cohort* (mean age = 22.06, range: 20.7-24.9).

Stimuli and procedure Two versions of six events were created. One version was designed to elicit relative clauses

and the other conjoined clauses. The relative clause versions of the events each depicted three characters (see Figure 1). The three characters were similar in appearance (same gender, similar physical features and coloring, similar clothing) but performed distinct identifying actions (e.g., one writing, one typing on a laptop, and one reading). Signers first saw individual clips depicting each character separately. Then signers saw a clip with all three characters together performing their respective actions, with a fourth individual watching the scene (see Figure 2). After a short period of time, the fourth individual leaves, and one of the three characters then engages in a new action (e.g., falls off a chair). Signers are asked to tell the fourth individual who had left the scene prior to observing the new action what happened.

The conjoined clause version differed from the embedded clause version in that the event portrayed only one character, instead of three characters (e.g., one character typing on a laptop then falling off a chair, see Figure 3). Here, the observing individual leaves prior to seeing any of the actions.

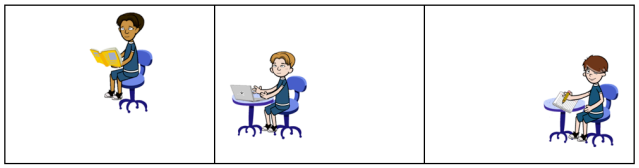

Figure 1. Example of the three characters in the relative clause stimuli. Each individual performs a different action (e.g., typing).

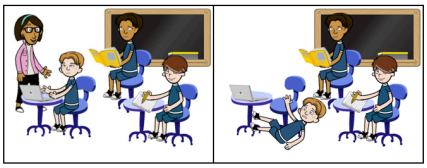

Figure 2. Example of new action in the relative clause stimuli. The left panel depicts all three characters with a fourth individual observing the scene. The right panel depicts a unique individual engaged in a particular action (e.g., falling).

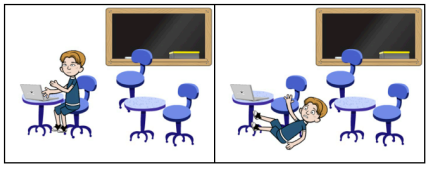

Figure 3. Example of conjoined clause stimuli.

The stimuli were normed on Amazon Mechanical Turk with monolingual English speakers. They were found to reliably elicit relative clauses (*the boy who was typing fell*) or reduced relatives (*the boy typing fell*) in the relative clause version, and conjoined clauses (*the boy typed and fell*, *the boy typed then fell*) in the conjoined clause version.

For the relative clause versions, signers first saw movies of the individual characters and were asked to describe each clip to ascertain that they interpreted the actions portrayed in the way we intended. Signers then saw the clip with all three characters and were asked to describe the event. For the conjoined clause versions, signers saw a single movie and were asked to describe the event. We filmed their descriptions for later analysis.

Coding Signed descriptions were coded for by the first author, a fluent signer of ASL (American Sign Language) with 8 years of research experience with NSL. Our coding centered on three levels of representation: *semantics* (differences in the discourse function of the descriptions), *syntax* (differences in the form), and *prosody*.

Semantics: We coded whether signers from all cohorts were able to fulfill the discourse function of relative clauses, picking out an individual from a set. In the relative clause version, the fourth individual in the scene sees the different actions of the characters (e.g., typing, reading, writing), but not the new action (e.g., falling). Because the fourth individual is aware of the different actions of individuals in the set, but not the new action of one individual, we expect that signers will identify the target individual when describing what happened, producing a description like *the boy who was typing fell*, contrasting the target with the other boys who were performing different actions (reading and writing). The establishment of a set and then the selection of an individual of that set is the semantic function that relative clauses serve, where the interpretation is one like: "There is a boy typing, a boy reading, and a boy writing. The boy who was typing fell" as opposed to "There is a boy typing, a boy reading, and a boy writing. The boy is typing and falls."

In contrast, in the conjoined clause version, there is a single character performing both actions. The observing individual leaves before seeing any of the actions. We expect that signers will produce what amounts to a conjoined clause, describing the scene as one where *a boy is typing and then falls*. Here, there is only a single character in the scene and the observer does not see the initial action, thus there is no identifying action that picks out a specific individual (e.g., the one who is typing). As such, a description of this event should semantically differ from a description in the relative clause version, where no set has been established.

Syntax: We coded one possible marker of form difference: the repetition and reduction in length of the verb that picks out the unique individual. Sign languages possess a rich system of verbal morphology, where signs can be inflected for person, number, location, and manner (see Padden, 1983; 1990). In ASL, verbs can be inflected through changes in movement to indicate aspectual information or in location to indicate subject-object agreement (Klima & Bellugi, 1979; Padden, 1983). Previous observation of NSL has noted use of a reduction in the

length of verbs as anaphor, suggesting this device may be a possible candidate for relative clause embedding.

In the relative clause version of our events, there is an opportunity to mention the individuating verb twice: the first when establishing the set (one boy *typing*, one boy reading, and one boy writing) and the second when describing the new action (the boy who was *typing* fell). Previous observations of NSL suggest that one possible marker of a relative clause is a reduction in the length of the verb the second time it is mentioned. The second, reduced mention of typing refers back to the boy who is typing, established at the beginning of the description.

In the conjoined clause case, there is no set of individuals and thus no action that individuates. As such, typing is only mentioned once, and does not serve as an identifier, but rather as a description of the first of two actions observed in the scene.

Prosody: We coded for differences in prosody. A relative clause (the boy who was typing fell) has a different prosodic structure than a conjoined clause (the boy was typing then fell). This difference may be marked with a longer pause or additional descriptions between mention of typing and mention of falling in the conjoined clause case compared to the relative clause case.

Results

The data were submitted to logistic mixed effects regression models with item and subject as random effects. For the analyses, we constructed separate logistic mixed effects models, with the trial coded as 1 when the variable of interest was present and 0 when it was absent. Cohort was coded using two dummy variables, with the first cohort acting as the baseline (the intercept). We compared two models: one model with cohort as a predictor variable and one model without cohort as a predictor variable.

First, we looked at whether signers from all three cohorts mentioned the identifying action of the target individual (e.g., typing) *and* the new action (e.g., falling). The model with and without cohort showed no significant difference, $F(3, 5) = 2.169$, $p = .338$ (Cohort 1: 97%; Cohort 2: 98%; Cohort 3: 100%). Then we examined whether signers established the set of referents from which the unique individual is picked out, specifically if they mentioned all three characters in the event. Again, we found no significant difference between the model with cohort and the model without cohort, $F(3, 5) = 4.042$, $p = .133$ (Cohort 1: 60%; Cohort 2: 73%; Cohort 3: 77%). Signers from all three cohorts established the set of referents and described the identifying action and new action of the target individual, providing robust evidence that all three cohorts have strategies to fulfill the discourse function of relative clauses.

The third analysis looked at whether signers repeated the individuating verb, as we would expect if they were producing a relative clause. If this device is developing in the language, we expect to see a difference across the cohorts. This was observed in the ANOVA comparison of the model with cohort and the model without cohort, $F(3, 5) = 5.314$, $p = .070$. We then conduced pairwise comparisons to determine where the differences among cohorts lay (see Figure 3). The difference between the first cohort and the second cohort was significant ($p < .01$), as was the difference between the first cohort and the third cohort ($p < .01$). The difference between the second and third cohorts was not significant ($p = .960$).

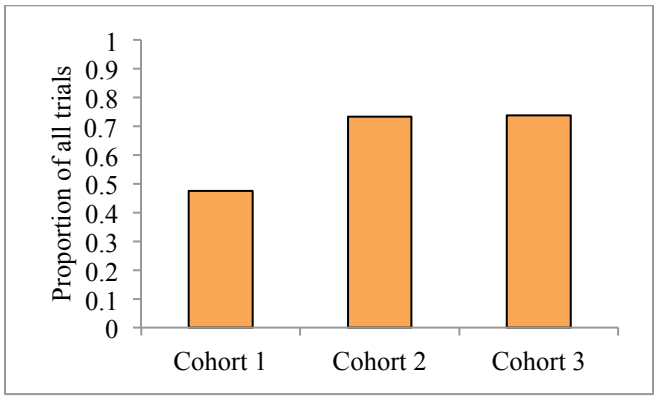

Figure 3. Proportion of trials in which signers repeated the individuating verb.

Finally, we looked at whether there was a reduction in the length of the second mention of the individuating verb. Here, we constructed linear mixed effects models for the comparison, computing the timing difference using a ratio of the length in milliseconds of the second mention of the individuating verb to the length of the first mention of the verb. The ANOVA analysis revealed that the model with cohort as a predictor performed significantly better, $F(4, 6) = 6.470$, $p = .039$ (see Figure 4). Follow-up comparisons revealed that the difference between the first and second cohorts was marginally significant ($p = .077$), and the difference between the first and third cohorts was significant ($p = .014$). The difference between the second and third cohorts was not significant ($p = .354$).

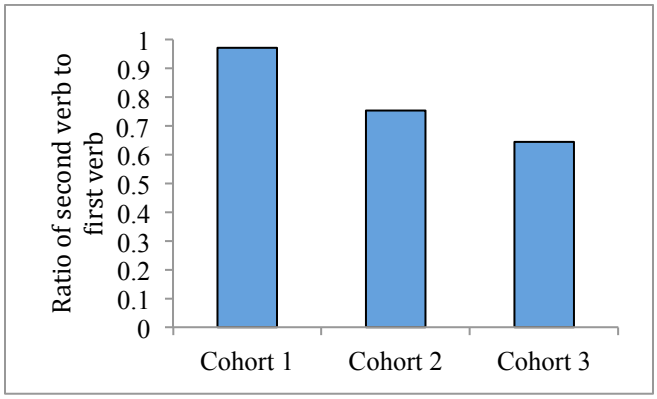

Figure 4. Ratio of second-mentioned verb to first-mentioned verb out of trials in which signers repeated the individuating verb.

Future work will analyze differences in descriptions of the relative clause stimuli and the conjoined clause stimuli.

Preliminary coding suggests that there are some prosodic differences as well as a greater number of words separating the two verbs in the conjoined clause descriptions compared to the two verbs in the relative clause descriptions, suggesting that descriptions with a relative clause differ prosodically from descriptions with a conjoined clause. We plan to do additional coding as well as perform a closer examination of the type of words that separate the two verbs in the two types of clauses (e.g., some words are related to the action encoded by the second verb).

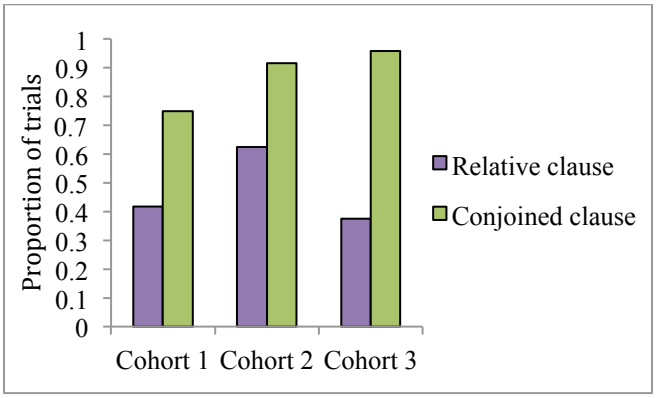

Figure 5. Proportion of trials in which words separated the two verbs in relative clause descriptions and conjoined clause descriptions.

Discussion

In the current study, we investigated whether the capacity to implement linguistic rules within rules (syntactic recursion) emerges early in a new language or if it must be constructed over historical time.

Our results suggest that signers from all three cohorts have strategies to fulfill the discourse function of relative clauses, namely picking out an individual from a set, producing semantically different utterances when describing a relative clause version of an event and a conjoined clause version. However, the grammatical form of the utterances differs across cohorts, with signers from later cohorts producing sentences with relative clauses. Specifically, third-cohort signers may be producing a reduced (shorter) form of the verb in the relative clause (the boy who was *typing* fell) compared to the first (longer) mention of the relevant individual and his action (there is a boy typing).

Follow-up studies will attempt to answer open questions from this work, ascertaining whether the prosodic differences observed between relative clauses and conjoined clause are indeed due to differences in form rather than differences in timing of the events. Future work will also test an alternative possible explanation for the reduction of verbs that we observed, namely that any subsequent mention of the same verb (rather than just the verb in a relative clause) is accompanying by a reduction in length.

The recent emergence of a sign language in Nicaragua offers us the opportunity to capture the creation and development of a new language. Here, we investigate whether linguistic rules that may allow for infinite expression are present in each individual human mind or if the formation and expression of these rules depend on social context and transmission across individuals. Early findings from this work suggest that syntactic recursion, while not appearing immediately in a new language, may nonetheless be an early-emerging property. Importantly, while we found suggestive evidence for syntactic recursion in the language of only the third cohort signers, signers from all three cohorts were able to express semantically different utterances, indicating that even if a language may not have syntactic recursion, human thought is recursive.

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