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Validating Silent Gesture Lab Studies in a Naturally Emerging Sign Language: How Order is Used to Describe Intensional Versus Extensional Events in Nicaraguan Sign Language

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Abstract

Languages are neither designed in classrooms nor drawn from dictionaries—they are products of human minds and human interactions. However, it is challenging to understand how structure grows in these circumstances because generations of use and transmission shape and reshape the structure of the languages themselves. Laboratory studies on language emergence investigate the origins of language structure by requiring participants, prevented from using their own natural language(s), to create a novel communication system and then transmit it to others. Because the participants in these lab studies are already speakers of a language, it is easy to question the relevance of lab-based findings to the creation of natural language systems. Here, we take the findings from a lab-based language emergence paradigm and test whether the same pattern is also found in a new natural language: Nicaraguan Sign Language. We find evidence that signers of Nicaraguan Sign Language may show the same biases seen in lab-based language emergence studies: (1) they appear to condition word order based on the semantic dimension of intensionality and extensionality, and (2) they adjust this conditioning to satisfy language-internal order constraints. Our study adds to the small, but growing literature testing the relevance of

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lab-based studies to natural language birth, and provides convincing evidence that the biases seen in the lab play a role in shaping a brand new language.

Keywords: Silent gesture; Language emergence; Nicaraguan Sign Language; Sign language

1. Introduction

All human societies have languages, but it is difficult to observe how these language systems come to be. Languages are not designed in classrooms or drawn from dictionaries—they are the products of human minds and human interactions. Most languages have long and largely undocumented histories. It is challenging to understand how structure first emerges in these systems because generations of use and transmission have both shaped *and* reshaped the grammars of the languages themselves.

Two distinct lines of research aim to address the origin of language structure: laboratory studies on language emergence, most of which employ a silent gesture methodology (adult hearing participants with no knowledge of sign languages are asked to use only their hands to communicate), and close observation of new natural languages. The origin of structure in natural languages is generally accepted to be the subject of interest in silent gesture studies. However, there is little evidence that can speak to whether the findings of silent gesture studies are applicable to how natural languages grow their structure. Here, we seek to bring together these two lines of work by examining a phenomenon previously found in a silent gesture lab study in a new natural language: Nicaraguan Sign Language.

Studies involving the creation of gestures are of particular relevance and interest to the emergence of communication in the manual modality. For example, in the first "silent gesture" study of its kind, Goldin-Meadow, McNeill, and Singleton (1996) found that when hearing nonsigner participants were required to describe motion events using only their hands and not their voices, their gestural descriptions displayed language-like regularities (such as the number of elements produced and the regularity of ordering in which those elements were combined) not present in the cospeech gestures they produced to accompany spoken descriptions of those same events.

In the years since Goldin-Meadow et al.'s path-breaking study, other researchers have documented emergent language-like structure in similar experimental scenarios employing silent gesture. A commonly investigated pattern in silent gesture research is the regularity in ordering nominal and verbal elements in gesture descriptions. Participants are asked to produce descriptions using gesture alone (without accompanying speech) to describe events in which an animate entity acts on an inanimate entity (e.g., a captain swings a pail). In these studies, researchers typically find a strong preference for producing gestures to describe the events in a consistent order—subject, object, verb (SOV, in this example, *captain pail swing*), regardless of the participants' language (Gibson et al., 2013; Goldin-Meadow, So, Özyürek, & Mylander, 2008; Hall, Mayberry, & Ferreira, 2013; Meir et al., 2017). For example, the SOV preference is found not only in speakers of languages with SOV word orders, such as Turkish and Kurdish, but also in speakers of languages with SVO orders, such as Hebrew and

English. Based on the consistency of these results, many have argued that SOV orders are foundational in human language.[1]

However, not all silent gesture studies find SOV orders to be most common for events in which an animate agent acts on an inanimate patient. Schouwstra and de Swart (2014) examined gesture descriptions of a wider semantic range of events and found significant variation in ordering based on whether events were extensional or intensional (see also Christensen, Fusaroli, & Tylén, 2016). Extensional events are those in which an (animate) subject acts on an existing, specific inanimate object (e.g., "boy eats cake"); intensional events are those in which a specific inanimate object does not yet—or does not necessarily—exist at the time the action in the event takes place (e.g., "boy thinks of cake" or "boy bakes cake"), or is unspecific (e.g., "boy wants cake"). Intensional transitive verbs have challenged existing formal accounts of natural language meaning, because they behave in ways (e.g., with respect to conditions for truth/falsity of sentences) that cannot be explained by these accounts (Forbes, 2020; Moltmann, 2008).

Gesture descriptions of extensional events followed the previously documented SOV ordering patterns attested in earlier work. However, in descriptions of intensional events, participants were more likely to use SVO ordering (Schouwstra & de Swart, 2014). This finding is consistent with the proposed explanation (Goldin-Meadow et al., 2008) that when people convey information, they prefer to present more specific information first, and more relational or abstract information later. For intensional events, the patient is either dependent on the action, or relatively abstract (patient information for intensional events is about the meaning or *intension* rather than about the object in the world); the patient is placed at the end of the sentence. By showing that word order is directly dependent on the semantic properties of the event, this line of work shows how word order can reflect preferences rooted in meaning that may be important for situations of language creation.

As mentioned above, a key question that the silent gesture literature cannot directly address is the relevance of these findings to the creation of naturally emerging language systems. In fact, despite the fact that ordering conditioned on this distinction is found consistently in silent gesture (Christensen et al., 2016; Schouwstra, 2017; Schouwstra & de Swart, 2014), natural languages rarely show ordering conditioned on extensional versus intensional meaning. Dryer (2013), for instance, discusses the ordering properties of 1376 different languages, characterizes the large majority of these as having a rigid word order, and does not mention intensionality as a potential driver of word order variation in any language. There is one exception: intensionality has been mentioned as a source of variability in one sign language, Brazilian Sign Language or Libras (Napoli, Spence, & de Quadros, 2017). This sign language has previously been characterized as SVO-dominant, and signers were shown to be more likely to deviate from (S)VO order for extensional events than for intensional events. For extensional events, (S)OV was more common. Apart from Libras, ordering variation based on the extensional/intensional distinction has not been attested (to our knowledge) in any existing languages. By contrast, other semantic effects (like that of animacy) have been found to have an influence on word order, not only in language emergence (Meir et al., 2017, Kocab, Lam, & Snedeker, 2018), but also in established languages (e.g., Tomlin, 2014; de Swart et al., 2008).

To summarize, the disparity between the silent gesture results and the patterns found in most established languages raises questions about what lab gesture studies can tell us about natural language emergence[2] and growth. Indeed, the conditions under which silent gesture is generated differ from the conditions leading to a new natural language in at least four ways. (1) Silent gestures are generated to describe a highly constrained and homogenous meaning space; natural languages are not. (2) Silent gestures are used for a few minutes in a lab; new natural languages are used for an extended period, by both individuals and communities. (3) Silent gestures are not always used to communicate with others; natural languages are always used for communication and are potentially shaped by that communication.[3] (4) Silent gestures are learned or transmitted by people who already have a first language and thus know how at least one natural language works; new natural languages generally are not. Each of these differences described here may be responsible for the (apparent) disparity between the silent gesture results and the patterns found in most established languages.

In order to overcome some of these differences, the silent gesture laboratory method has recently been extended to include communication between participants, and transmission to new learners in various recent experiments (e.g., Motamedi, Schouwstra, Smith, Culbertson, & Kirby, 2019; Nölle, Staib, Fusaroli, & Tylén, 2018), thereby mitigating differences (2), (3), and (4). Experimental work that focuses specifically on word order variability and how this develops under the influence of learning and/or interaction shows only subtle effects: under some circumstances, word order variability reduces as an effect of interaction (Schouwstra, Naegeli, & Kirby, 2022), or learning (Motamedi et al., 2022), but generally a persistent influence of verb semantics on word order is observed, even after learning or repeated interaction. Specifically, Motamedi et al. (2022) combine their experimental data with evolutionary computational modelling and show a stable influence, even over many generations of language learning, of extensionality/intensionality properties of the verb on word order. They suggest that two forces exist in competition: on the one hand, a tendency to consistently use the same basic word order across semantic domains, and on the other hand a preference to condition word order on semantic properties. Finally, they predict that conditioning of word order on intensionality will be present in at least some natural languages. This poses a puzzling contrast with the apparent scarcity in the documentation of such patterns in existing languages, as we described above. And this in turn might raise questions about whether lab gesture studies can indeed inform our understanding of natural language emergence and growth. In what follows, we outline our views on word order patterns and variation, and explain how this is relevant in connecting silent gesture study observations with typological data.

Though the possibility has not been widely considered in the literature, it is entirely possible that natural languages with relatively flexible word order show conditioning based on extensional versus intensional meaning, but in the form of a subtle tendency rather than a strong pattern. To this end and in contrast to most other work on order in silent gesture and natural language emergence, in this paper, we aim to incorporate a gradient view of word order patterning that will allow us to find this more subtle type of pattern when it exists. With the availability of more and more corpus information that offers fine-grained and graded information on word order, Levshina (2022), for example, persuasively lays out that word order patterns within a language are in fact rarely categorical. It is quite typical for a lan-

guage to display variable word order and such variation can be a stable pattern for hundreds of years. We, therefore, investigate the frequency with which different word orders are used, rather than trying to decide which is the "dominant" word order. This process thus allows us to identify multiple, potentially conflicting, pressures within a language on its ordering.

To be specific, language-internal constraints might have an effect on the orders used to express intensional versus extensional events: utterance orders may reflect both patterns found in silent gesture studies as well as language-internal syntactic pressures. Multiple different pressures affecting ordering may also yield changing ordering patterns over the history of a language, especially in its earliest years. We aim to focus on the case of Nicaraguan Sign Language, which has a known verb-final pattern, and is also quite young. We will investigate how intensional and extensional meanings are conveyed in this language, to see how patterns observed in the laboratory are reflected in a natural system in the earliest years of its existence.

Nicaraguan Sign Language (LSN) was born in the late 1970s in Managua with the opening of the first school for special education. In this school, deaf children from around the city (and some from outside) came together in larger numbers and for longer periods than had previously happened in Nicaragua. Teaching at the school was conducted exclusively in Spanish, but children were not prohibited from communicating manually with one another. Within a short time, hearing teachers at the school reported that they could no longer understand what the children were communicating to each other (Polich, 2005). This was the very beginning of LSN. As children continued to enter the school each year, they learned the language from their older signing peers. But they did not just learn the language; they changed it (Senghas, 2003; Senghas, Kita, & Özyürek, 2004). The language itself has grown and changed as it has continued to be learned, used, and passed down to new generations of signers. There are approximately 1500 signers[4] of Nicaraguan Sign Language today. The beginning of the new natural language in Nicaragua is exactly the phenomenon that silent gesture studies attempt to approximate in the lab: the birth of a new language. If silent gesture studies inform us as to how human languages are shaped by human communication and learning, then we would expect to find parallel emergence effects in LSN.

Here, we ask whether the different ordering patterns found in silent gesturers' descriptions of intensional (SVO) versus extensional (SOV) events are also found in LSN. If so, we ask whether signers display differences in their ordering patterns as a function of the year in which they entered the deaf community. Signers who arrived first at the school and if possible co-constructed the new language might display different patterns from signers who entered the school several decades later and learned the already flourishing LSN from older peers (see, e.g., Rissman et al., 2020). Alternatively, because order is a robust aspect of language learning (Newport, 1990), there may be no differences in ordering patterns in signers as a function of when they entered the community (see, e.g., Gleitman, Senghas, Flaherty, Coppola, & Goldin-Meadow, 2019). LSN thus provides an ideal opportunity to determine if and how the forces giving rise to ordering patterns in improvised silent gesture are reflected in the structure of a new natural language.

Importantly, we are *not* attempting to run a silent gesture study with Nicaraguan signers. In silent gesture studies, participants are prevented from using their native language to communicate and must spontaneously generate a new gestural system. In contrast, here we

Table 1
Stimuli given to the LSN signers

Object	Extensional event	Intensional event
bracelet	Woman holds a bracelet	Man makes bracelet
bubble	Woman pops a bubble	Woman blows bubble
cake	Man eats cake	Woman likes/wants cake
cake piece	Man eats cake piece	Woman likes/wants piece of cake
cup	Woman flips cup	Man turns to notice cup
glove	Woman throws glove	Woman searches for glove
pot	Woman drops pot	Woman makes pot on potting wheel
shoe	Man throws shoe	Man searches for shoe

aim to elicit naturalistic descriptions in Nicaraguan Sign Language of extensional and intensional events.

2. Method

2.1. Participants

Twenty-six signers of LSN (12 women, 14 men) were recruited via the first author's contacts to participate in the task. All signers first encountered LSN before the age of 6 upon first entry to school. Participants entered school over a period of 25 years between 1973 and 1998.

2.2. Materials

Participants viewed a series of 16 short video vignettes. These vignettes were inspired by the line drawing stimuli created by the second author to elicit gesture descriptions of extensional and intensional events (Schouwstra, 2012; Schouwstra & de Swart, 2014). In each event, there was one animate agent/subject and one inanimate patient/object. The animate agent in each event was either a woman ($n = 10$) or a man ($n = 6$). For example, a man throws a shoe (extensional). Or a woman looks for a glove (intensional). A full list of extensional and intensional events in our stimuli can be found in Table 1.

The events for the video vignette stimuli were chosen with several criteria in mind. First, events were selected from the original stimuli if they were appropriate to Deaf Nicaraguan culture; events not appropriate to the culture (e.g., events about knitting scarves) were discarded. Second, only events that could be depicted visually in a short video were selected; other events were discarded (e.g., thinking of a sock was not easily depictable in a short live action video). New events not used in the original study were developed in accordance with these criteria. The first author has more than 15 years of experience creating stimuli that are culturally relevant and understandable to members of the Nicaraguan deaf community. Based on this expertise, we created video events rather than line drawings, as this has previously been a more successful elicitation technique in this community. Furthermore, using

video stimuli adapted to the Nicaraguan signing community context allowed us to avoid the type of specific culture-bound visual drawing conventions used in the original Schouwstra and de Swart stimuli (i.e., thought bubbles) that are not generally familiar to members of the Nicaraguan deaf community.

In total, there were eight pairs of events, each pair depicted an object in an intensional context in one vignette (e.g., blowing a bubble) and the same object in an extensional context in another vignette (e.g., popping a bubble). In the intensional version of the event, the object was created, desired/liked, noticed, or sought, such that the object was brought into being by the intensional action. In the extensional version of the events, that same object was acted upon (i.e. thrown, dropped, or moved). These two contexts were kept as similar as possible so that any differences observed between the two contexts were likely to be due to the contrast between extensionality and intensionality. An additional two pairs of events were shown to participants but the intensional versions of these events never elicited intensional descriptions (participants signed STACK BLOCKS, an extensional event, rather than the intended BUILD WALL, an intensional event; they signed WRITE LINES ON WHITEBOARD, an extensional event, rather than DRAW A WATERMELON, an intensional event); these two pairs of events (four events in total) were thus excluded from order coding (independent of the order participants used to describe them) and further analysis. See Figure 1 for images from the video stimuli.

2.3. Procedure

After viewing and describing two extensional training events to ensure that the task was clear, participants viewed the 20 target events (eight pairs that were used, two that were eliminated) in a semi-random order (constrained so that the intensional and extensional versions of an event were never adjacent in presentation) on a laptop. After viewing each event, they were asked to describe what they saw to another signer of similar age (their communication partner), who could not see the laptop screen. The last frame of each vignette remained visible on the screen as participants produced their descriptions. Participants were not given any guidance as to how they should describe the scenes, but the experimenter periodically checked in with the communication partner to make sure the partner understood the descriptions produced. The signer understood that their communication partner could not see the video stimulus and so required a complete description in order to be understood, thus introducing a realistic communication pressure into the experimental situation. All responses were videotaped for later offline coding.

2.4. Coding and reliability

Coding video responses was completed by the first author who has 15 years of experience with LSN. All the signs in each utterance produced in response to the eight pairs of events were glossed as a function of the semantic element they referred to—the agent/subject, the patient/object, or the action/verb. The utterance was then coded for the order in which the signs referring to the subject, verb, and object were produced. A second coder with 3 years

Fig. 1. Sample extensional (a woman flips a cup) and intensional (a man notices a cup) stimuli.

of experience with LSN independently coded 13% of the data (50 utterances) for sign order. Interrater agreement was 98% ($\kappa = .962$).

3. Results

Because the silent gesture paradigm that inspired this study elicited primarily SOV and SVO orders in gesture, we begin our data analysis by focusing on these two orders, despite the fact that we might not expect to find *any* SVO sentences in LSN given the language's strong preference for verb-final orders. Data and analysis scripts of this and the following model can be found on our OSF repository.[5] Of the 413 LSN utterances produced by signers,

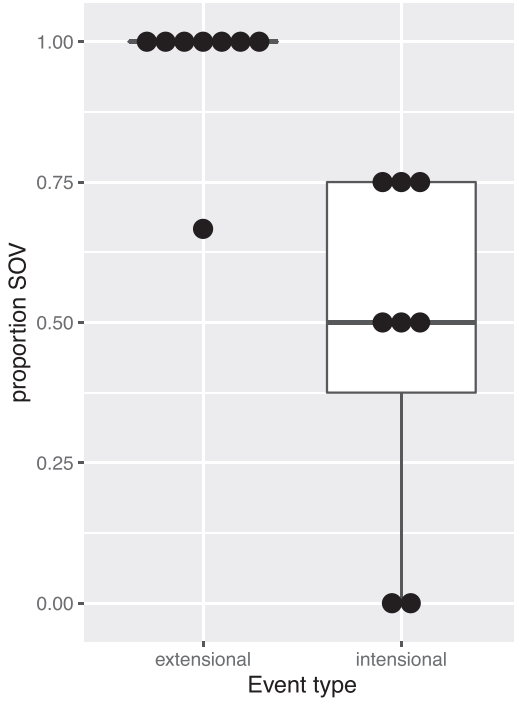

Fig. 2. Proportions of SOV orders produced in response to extensional versus intensional events by the eight participants who produced both SVO and SOV orders. Each dot represents the proportion of SOV orders (number of SOV utterances / total number of utterances containing just S, V, and O) for an individual participant. As participant descriptions were not tightly constrained, participants' total numbers of utterances varied. Extensional events elicited more SOV orders than intentional events ($p = .020$, Wilcoxon signed rank test).

105 contained all three elements (V, S, and O) in either an SOV or SVO order. Most of these utterances followed an SOV order, which is not surprising given that LSN has a strong bias toward verb-final utterances (Flaherty, 2014). Within the 95 SOV sentences, 73 (77%) were produced in response to extensional event stimuli; the remaining 23% were produced in response to intensional event stimuli. Remarkably given the overwhelming verb-finalness of LSN, participants did produce 10 SVO utterances. Of those 10 utterances, nine (90%) were in response to intensional event stimuli; one SVO utterance was produced in response to extensional event stimuli. Eight participants produced at least one SOV and at least one SVO sentence; seven of these eight signers produced proportionally more SOV sentences for extensional events than for intensional events. This effect was significant, as confirmed by a Matched Pairs Wilcoxon signed rank test ($V = 35$, $p = .02$; see Fig. 2). As one would expect in a language with such a strong verb-final pattern, SVO sentences are extremely rare. But when they do occur, they occur far more often to describe intensional events than to describe extensional ones. This result is broadly consistent with the pattern found in silent gesture (adjusting for the fact that LSN disprefers utterances that do not end in V)—a preference for SOV to describe extensional events, and a preference for SVO to describe intensional events.

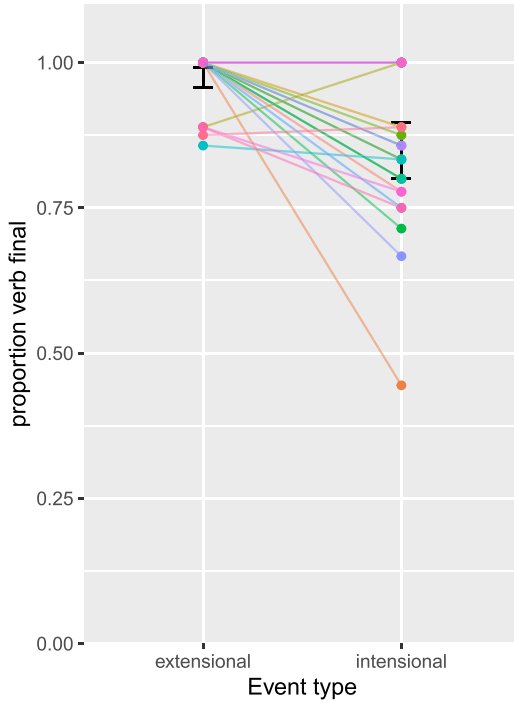

Fig. 3. Proportions of verb-final utterances for extensional versus intensional events. Each dot represents a signer and each line connects the two means (extensional and intensional) for each signer. The results show that signers were more likely to break the verb-final pattern (the dominant pattern in LSN) for intensional events than for extensional events.

However, a significant drawback of this comparison is that it only allows us to look at a very limited portion of our data.

Responses in the silent gesture studies contained, for the most part, gestures for each of the three elements in the event (V, S, and O) and only for these three elements. If we wish to look for a similar pattern in a natural language, however, we need to consider the syntactic structure of that language. In this case, that means taking seriously the fact that LSN utterances only very rarely end with a nonverb element, so just comparing SOV and SVO utterance frequency will not allow us to find possible ways that LSN does condition order on intensional versus extensional meaning. Indeed, LSN signers primarily produced more elaborate descriptions of the events, which contained multiple V's, S's, and O's, and which accounts for the small number of SOV or SVO utterances in the data. But, as just mentioned, LSN is a strongly verb-final language: 377 (91%) of the 413 utterances produced by the signers were verb-final. In order to use all of the data that the signers generated to address our question, we categorized each of the utterances that the signers produced as either verb-final or not. On the basis of the silent gesture findings that objects are more likely to follow verbs in intensional events than in extensional events, we reasoned that descriptions of intensional events ought to be less likely to follow LSN's verb-final convention than descriptions of extensional events. Fig. 3 presents

the proportion of verb-final utterances produced by each participant for extensional versus intensional events, and shows that 17 signers displayed this predicted pattern. Six signers used only verb-final utterances. Two did not use verb-final utterances all of the time, but showed no pattern conditioned on extensionality when they did (verb-final utterances were used equally for extensional and intensional events). Only one of the 26 signers showed a pattern in the opposite direction from the predicted pattern, producing proportionally more verb-final utterances for intensional events than for extensional events.

To statistically compare verb-final utterances in descriptions of extensional and intentional events, we conducted a logistic mixed effects regression, entering a fixed effect of event type (sum coded), random effects for stimulus item, and by-signer random slopes and intercepts for event type.[6] The analysis confirmed that overall, utterances were more likely to be verb-final than non-verb-final, as reflected in the model intercept ($\beta = 2.89$, $SE = 0.53$, $p < .001$), and significantly less likely to be verb-final for intensional events than for extensional events ($\beta = -1.99$, $SE = 0.57$, $p < .001$). Thus, as predicted on the basis of the silent gesture findings that objects are more likely to follow verbs in descriptions of intensional events than extensional events, utterances describing intensional events in LSN are more likely to break the verb-final rule than utterances describing extensional events.

To assess whether a signer's year of entry into the community influenced how likely the signer was to follow the dominant pattern in Fig. 3, we ran a binomial mixed effects regression (using R, R Core Team, 2020 and lme4, Bates, Mächler, Bolker, & Walker, 2015), predicting whether or not an utterance was verb-final and including year of entry and event type. Event type was sum coded, and year of entry was first rescaled onto values between 0 and 1,[7] and subsequently centered. We also entered by-signer and by-item random intercepts (more complex models resulted in singular fit). The model confirmed an effect of event type ($\beta = -2.18$, $SE = 0.62$, $p < .001$), but did not show a main effect of year of entry ($\beta = -1.22$, $SE = 0.94$, $p = .19$). Thus, we could not confirm a relation between the tendency to produce verb-final utterances and year of entry. In addition, the model did not confirm an interaction between event type and year of entry ($\beta = 1.92$, $SE = 1.81$, $p = .29$). There was no evidence in our data that the difference in verb-final behavior depended on year of entry.

4. Discussion

We have found that word order in LSN is sensitive to the extensional-intensional meaning dimension, especially when we dive deeper to take into account ways in which this pattern may show up in a language in accordance with its internal syntactic constraints. The patterns found in LSN are not identical to the pattern found in the silent gesture literature, but they are consistent with the lab findings. Because LSN is a strongly verb-final language, 91% of the utterances produced by the signers contained a verb at the end, which means that SVO sentences are extremely rare. Despite this language-internal constraint, we find that signers who produce both SVO and SOV utterances do use SVO to describe intensional events. Also consistent with the pattern found in silent gesture, we find that the intensional-extensional meaning dimension had an impact on where signers deviated from the verb-final

pattern—signers were more likely to end a sentence without a verb when describing intensional events than when describing extensional events. The bias for objects to follow verbs in descriptions of intensional events thus manifests itself within the constraints of LSN. The selective deviation from the dominant verb-final pattern in LSN is a compromise between the individual bias in constituent ordering seen in the silent gesture studies (SVO used for intensional events and SOV used for extensional events) and the emergent rules of this new language (to put the verb at the end of the utterance). Ordering elements in intensional and extensional events is a striking example of the way in which bias for semantic conditioning can integrate with a language's grammatical rules to create a cohesive system.

In our study, we did not find an effect of year of entry into the deaf community on the intensional-extensional ordering patterns; these patterns were already present in signers who entered the community first. This finding is consistent with a scenario in which something akin to the kind of conditioning found in the silent gesture literature was present in the earliest stages of LSN. The preference for verb final orders in LSN appears in even the oldest signers (see, e.g., Abner et al., 2019). LSN is strongly verb-final, but our findings suggest that this convention can be violated for intensional events, and that these violations are present from the inception of the language. We suggest that individual signers bring with them a bias to place the object at the end of an utterance in descriptions of intensional events. Napoli et al. (2017) suggest that this bias is an iconic reflection of the semantic structure of intensional events—the object appears only after the action has taken place, which results in a VO order. This bias comes into conflict with the bias to use a single word order for all simple events (i.e., for events involving an animate agent and an inanimate patient), which overrides but does not eliminate the bias to treat intensional events differently from extensional events.

The lack of reported similar patterns in spoken languages might raise the concern that word order conditioning on the extensional-intensional meaning dimension is a modality-specific effect. We cannot rule out this possibility, but we see no compelling reason why this should be the case. If lab-based emergent communication studies have relevance only to the creation of new manual communication systems, this poses a major problem for most of the claims made within this subfield, as researchers in this area claim to be investigating language, communicative, or learning biases relevant to all language learning and creation. We believe the modality question will require further investigation in the future. Encouraging results were observed in a vocal improvisation experiment, in which lab participants invented novel nonword vocalizations to convey information about transitive events (Mudd, Kirby, & Schouwstra, 2018). Participants (all speakers of English) in this study were asked to produce nonword linguistic vocalizations (i.e., an "evil laugh" for witch or "boom" to denote the action of dropping) to describe line drawings of extensional and intensional events. In this study, they showed a relatively large preference in favor of SVO throughout, but used SOV significantly more often for extensional than for intensional events. Similarly, traces of word order conditioning based on intentionality might exist in spoken language data, but this is, at the moment, a largely unexplored empirical question (see more on this below).

These findings point to two areas in which future studies would be informative. First, we can ask which develops first—the intensional-extensional word order bias, or the bias to use the same order for all types of events involving animate agents and inanimate patients. To

address this question, we can observe word order biases in homesigners. Homesigners are deaf individuals born into hearing households whose hearing losses mean they do not acquire the spoken language that surrounds them, and who have not been exposed to a conventional sign language. When the school in Managua was first opened, it brought together homesigners, none of whom knew each other. Each had developed a gestural system of homesigns to communicate with their hearing family members. Homesigns have been shown to have many, although not all, of the structural properties of natural languages (Goldin-Meadow, 2003, 2023). There have been no studies of how homesigners describe intensional versus extensional events, primarily because intensional events are rarely the focus in spontaneous communication. Presenting the stimuli used by Schouwstra and de Swart (2014) to current day homesigners in Nicaragua would give us the opportunity to determine whether homesigners have a bias to use different orders to describe intensional versus extensional events, as well as a bias to use the same order to describe all events. With these data, we would then have a better understanding of the foundation on which LSN was initially built.

Second, we can explore the breadth of the bias to use different orders to describe intensional versus extensional events in other (older) natural languages. Although this type of conditioning has not been reported in *spoken languages*, we suspect that traces of the conditioning on intensional-extensional meaning can be found in these languages as well. For example, if we look at a spoken language with relatively free word order, we suspect that objects will be more likely to follow verbs in descriptions of intensional events than extensional events. Corpus studies that allow for token-based typological analysis (Levshina, 2021) might be able to detect these traces.

In sum, we brought a question from lab studies of language emergence to the investigation of a new natural language. By closely aligning our questions and methods, we were able to document commonalities between the lab and natural situations. By doing this, we also pointed out how the patterns observed in LSN might be the result of meaning-dependent variability in word order, combined with the constraints of a verb-final linguistic convention. This characterization contributes to our understanding of the processes that shape language at both individual and group levels, and also confirms the relevance of lab-based experiments to questions of language emergence.

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Notes

1 SOV orders are generally discussed as foundational to human language in the context of events where an animate agent acts on an inanimate patient. Reversible events, in

which an animate agent acts on an animate patient, show more variability in silent gesture studies. As intensional reversible events are rare (inanimates do not typically lead to the creation of animates), we discuss only nonreversible animate agent and inanimate patient events in this paper.

2 In using the term emerging sign language, we refer to the shared linguistic conventions that emerge when a new language community forms. We recognize that linguistic conventions in any linguistic community constantly appear, disappear, change, and shift, and will never stop doing so. The contrast we wish to draw between "emerging sign languages" and other languages is that for emerging languages there was no set of shared conventions just a few decades ago.

3 Recent work *does* implement silent gesture in an experimental setup that involves communicative interaction (Christensen et al., 2016) or interaction combined with iterated learning (Motamedi et al., 2019; Schouwstra, Smith, & Kirby, 2020). We will discuss this work in more detail in the discussion section.

4 This 1500 figure is a count of LSN signers who learned to sign in childhood (before the age of 6). In order to separate the effects of being a user of a very young language from the effects of being late-exposed to one's first language, we include only early exposed signers in our study.

5 See https://osf.io/tdsxw/. The published data do not contain details about the year of entry to the community due to the small population and potential privacy issues. For this reason, only the first two statistical analyses are made public.

6 See https://osf.io/tdsxw/?view_only=a7b93b500c6f4527bef0c2a58456106b for analysis code and data.

7 Rescaling was done to solve convergence issues in the binomial model. Values were obtained by subtracting the earliest year of entry from all values, and then dividing all resulting values by the highest of those values.

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