



## Original Articles

## The emergence of temporal language in Nicaraguan Sign Language

Annemarie Kocab<sup>a,\*</sup>, Ann Senghas<sup>b</sup>, Jesse Snedeker<sup>a</sup><sup>a</sup> Harvard University, Department of Psychology, Cambridge, MA, USA<sup>b</sup> Barnard College, Department of Psychology, New York, NY, USA

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## ABSTRACT

Understanding what uniquely human properties account for the creation and transmission of language has been a central goal of cognitive science. 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. Here, we examined the emergence of two types of temporal language in NSL, comparing the linguistic devices for conveying temporal information among three sequential age cohorts of signers. Experiment 1 showed that while all three cohorts of signers could communicate about linearly ordered discrete events, only the second and third generations of signers successfully communicated information about events with more complex temporal structure. Experiment 2 showed that signers could discriminate between the types of temporal events in a nonverbal task. Finally, Experiment 3 investigated the ordinal use of numbers (e.g., *first*, *second*) in NSL signers, indicating that one strategy younger signers might have for accurately describing events in time might be to use ordinal numbers to mark each event. While the capacity for representing temporal concepts appears to be present in the human mind from the onset of language creation, the linguistic devices to convey temporality do not appear immediately. Evidently, temporal language emerges over generations of language transmission, as a product of individual minds interacting within a community of users.

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## 1. Introduction

Human languages are complex symbolic systems, found in all human societies. No other animal has a communication system that has the scope and complexity of human languages, and no other animal can acquire such a system as readily as humans can. Thus there must be something unique about being human that allows for the creation and transmission of language. Identifying this property has been a central goal of cognitive science. Two broad classes of answers have been proposed. The first possibility is that language is a direct consequence of our mental architecture, and thus the capacity to create language is present in every human mind. For instance, perhaps the language faculty itself is a part of our genetic endowment (e.g., Chomsky, 1968, 2000; Pinker, 1994) or perhaps language is a product of more general changes in our conceptual resources and computational abilities (e.g., Christiansen & Chater, 2008). On this view, language is a window into the mind, and its properties and organization reflect the struc-

ture of human cognition (Chomsky, 1975; Pinker, 2007). The second broad 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). From this perspective, language is a side effect of the human capacity for social learning and cultural transmission (e.g., Tomasello, 2008). Since direct evidence on the origins of language is difficult to come by, arguments for these two alternatives tend to rest heavily on the theorist's prior assumptions about what kinds of learning and evolutionary change are or are not plausible.

Recently, however, a new tool has appeared for exploring this question. By studying emerging sign languages, such as Nicaraguan Sign Language (NSL), we can gain new insights into the time scale of language creation, which provide hard constraints on the role of historical processes and cognitive predispositions. This research program has painted a more nuanced picture of how historical and cognitive processes interact, suggesting that the answer varies depending on the phenomenon of interest (e.g., Flaherty & Senghas, 2011; Pyers, Shusterman, Senghas, Spelke, & Emmorey, 2010; Senghas, 2003). We suggest that many features of language do not emerge in one step from a single human mind acting in

\* Corresponding author at: Department of Psychology, Harvard University, 33 Kirkland Street, Cambridge, MA 02138, USA.

E-mail address: [kocab@fas.harvard.edu](mailto:kocab@fas.harvard.edu) (A. Kocab).

isolation, nor do they require long periods of historical evolution. Instead these elements emerge over the span of a few generations, suggesting that convergence on these forms does not require prolonged historical evolution, but may require a community of users, a process of transmission, and in some domains, sequential age cohorts of child learners.

NSL is a new language created by a deaf community in Managua, Nicaragua over the past four decades. Before the 1970s, there were few opportunities for deaf people to gather together and interact, and consequently Nicaragua had no standardized sign language. But in the mid-1970s and early 1980s, the government opened a new primary school for special education, followed by a vocational program for adolescents, and for the first time, deaf Nicaraguan children and adolescents were able to gather together in large numbers (Polich, 2005). Lessons were in spoken Spanish and instruction focused primarily on lip-reading and speaking Spanish, but were met with limited success. The children, however, like deaf students everywhere, began communicating with each other through gestures, and a new sign language emerged (Kegl & Iwata, 1989) that continues to develop to this day. Each successive group of children who enters the community introduces linguistic complexity into the language that adults evidently do not acquire (Senghas, 1995; Senghas & Coppola, 2001). This situation gives rise to a distinctive pattern in the language community, where the older signers, the initial creators of the language, represent earlier stages of the language relative to younger signers (Senghas, Kita, & Özyürek, 2004). To capture the changes in the language over time, researchers initially compared the language of the first cohort of children who entered the community in the late 1970s and early 1980s, to a second cohort of children who entered the community in the late 1980s. 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.

Previous work on NSL has found that different properties of the language have emerged over time and across these cohorts. Taken together, the findings suggest, first, that language is not solely an individual achievement—some properties emerge only over time within a social context—and second, that language, or at least these properties of language, are also not the product of slow process of cultural evolution—the time scale is one of decades rather than millennia (cf. Tomasello, 1999).

The seeds of language are present in individuals, as evidenced by the creation of gestural communication systems by deaf children who are not exposed to a manual language they can acquire. These *homesign* systems possess some key properties of language, such as vocabulary, grammatical categories, and word order (e.g., Goldin-Meadow, 1979; Goldin-Meadow, Butcher, Mylander, & Dodge, 1994; Goldin-Meadow & Feldman, 1975; Goldin-Meadow & Mylander, 1983). The first cohort of NSL signers, drawing on their gestures and homesign (Coppola, 2002; Coppola & Newport, 2005), created an ordered system with a stable lexicon that enabled them to express abstract thoughts beyond their immediate surroundings (Richie, Yang, & Coppola, 2013; Senghas, 1995; Senghas & Coppola, 2001). Other early-emerging elements of the language used by the first cohort of signers include words for cardinal numbers, a distinction between the syntactic categories for nouns and verbs, and devices for indicating argument structure (Flaherty & Senghas, 2011; Flaherty & Goldin-Meadow, personal communication; Senghas, Coppola, Newport, & Supalla, 1997). With the appearance of the second cohort there emerged systematic ways of describing spatial relations (*to the right of*, *to the left of*), using spatial morphological marking to indicate the roles of the patient and recipient in an event, and language to express mental states (Pyers & Senghas, 2009; Pyers et al., 2010; Senghas, 2003).

This body of work, along with work in other domains (e.g., Goldin-Meadow, 2003), demonstrates that some features of

language, those reflecting properties of individual minds (as seen in homesign systems) are immediately or very quickly available at the onset of the creation of a new language (e.g., Flaherty & Senghas, 2011; Richie et al., 2013; Senghas & Coppola, 2001), while other aspects, perhaps those requiring reiterated learning, take longer to emerge (e.g., Pyers et al., 2010; Senghas, 2003).<sup>1</sup> NSL contains many features that have been observed in other languages that are thought to be universal, including a stable lexicon, the grammatical categories noun and verb, and words for abstract concepts. Additional features that are observed in mature sign languages, such as a grammatical use of space, have emerged within two generations. Accordingly, the language of each age cohort of signers differs from the language of the cohort that preceded it, indicating a role for social interaction and learning.

The present study explores a new domain – temporal language – to continue the exploration of which concepts and devices emerge rapidly, and which appear over a few generational transitions. This work provides evidence regarding aspects of grammar that may depend heavily on intergenerational processes. Time is a rich area of study because temporal language encodes basic features of experience that all animals must be able to represent, such as order and simultaneity, but it does so in a highly abstract way, allowing these concepts to be generalized across time scales and over a variety of events. Temporal relations are critical for social communication: they provide structure to a narrative, they anchor causal explanations, and they are central in providing useable instructions. Accordingly, every language needs means to express temporal relationships, though the specifics of how they do it varies.

There are several reasons to expect that the expression of time might emerge early in a language. Primitive representations of time, fundamental to learning and survival, are available to all living creatures (Carr & Wilkie, 1997; Gallistel, 1990; Wilkie, 1995). Making sense of the world requires segmenting a stream of perceptual input into events. All events, from hearing human speech to tracking an object in motion, are perceived over time. Engaging in spatial and causal reasoning requires an understanding of temporal structure (Nelson, 1996), and understanding the behavior of agents and objects requires temporal concepts such as *before* and *after* (e.g., understanding that the window was in pieces *after* the ball hit it). Unsurprisingly, the ability to perceive temporal relations has been detected in early infancy (e.g., Bahrick, 1988; Chang & Trehub, 1977; Demany, McKenzie, & Vurpillot, 1977; Gardner, Lewkowicz, Rose, & Karmel, 1986; Lewkowicz, 2000). Given the cognitive importance of time, the early development of temporal perception, and the critical role of time in communication, one might predict that temporal language would emerge early in the creation of a new language.

However, there are also strong reasons to expect that the emergence of temporal language might depend on social and cultural processes that extend across generations. First, many temporal terms refer to time scales and relations that are quite different from the simple temporal relations that are needed for basic event perception and causal analysis. Language encodes abstract notions of time that cannot be directly mapped onto anything in our moment-to-moment experience, like *yesterday*, *tomorrow*, and *forever*. Furthermore, languages differ in how they describe time. This is true not only for temporal concepts that are clearly cultural

<sup>1</sup> It is useful to distinguish between two kinds of changes in a language. The first is directional change, or the growth of a new language and the creation of new resources over historical time, which is the focus of this paper. The second is historical change, or changes in a language that do not necessarily increase its level of complexity but instead reflect a constant flux due to contact, cultural shifts, and infidelity in the learning process. The point at which directional change ends and historical change begins is a question not addressed here.

constructs (e.g., *September*, *Tuesday*, *hours*, and *millennia*) but also for temporal concepts that are more likely to be universal (e.g., *day*, *night*, *before*, *after*). Languages vary in the linguistic forms used to convey temporal information including: bound inflectional and derivational morphemes (like tense/aspect markers), free grammatical morphemes (like conjunctions), syntactic constructions (like relative clauses), and lexical items (like temporal adverbs) (e.g., Berman & Slobin, 1994). For instance, in English we must consistently mark whether an event occurred in the past, present or future relative to the moment of speaking and a reference time in the discourse. In the sentence “John was going to eat the apple” the past tense marking in the verb *was* indicates that the event occurred in the past, prior the moment of speaking, while the future indicated in *going to* refers to a future relative to that reference time (in the past).<sup>2</sup> Aspectual information—such as whether an event has an end point and whether that endpoint was reached—is coded indirectly through a combination of verbal inflection, particles, and verb arguments. For example, in the sentence *John drank soda* the action has no explicit beginning or end, while the sentence *John drank a soda* implies a single, completed event. In English, tense and aspect can be conflated, where, for instance, the *-ed* at the end of a verb like *stopped* conveys past tense and perfective aspect. Many other languages, including American Sign Language (ASL) and Chinese are tense-less but encode aspect more consistently and directly (Klima & Bellugi, 1979; Lin, 2006; Rathmann, 2005; Smith, 1994).

Tense and aspect are not the only means of providing information about temporal relations in language. For example, ASL, in addition to a rich verbal aspectual system, also makes use of pragmatic context, temporal adverbs (e.g., *while*, *during*), and modality-specific devices such as *simultaneous constructions* (e.g., Emmorey, 2002; Rathmann, 2005). Simultaneous constructions can reflect either perceptual structure or discourse structure. When used to reflect perceptual structure, simultaneous constructions convey information about the spatial or temporal relationship between referents or events (Perniss, 2007). In simultaneous constructions, the two hands typically represent two different events, or parts of an event. The temporal relationship between the two hands as they move, simultaneously or sequentially, encodes the temporal relationship between the events. The use of simultaneous constructions has been observed in multiple sign languages, including ASL, Danish Sign Language, German Sign Language, Irish Sign Language, and Quebec Sign Language (Engberg-Pedersen, 1993, 1994; Leeson & Saeed, 2002; Liddell, 2003; Miller, 1994; Perniss, 2007).

A second reason that one might not expect temporal language to emerge immediately in a new language comes from studies of children that suggest that there is a gap between the temporal concepts that are provided by prelinguistic cognition and the temporal concepts encoded by language. Although children begin using tense and aspect morphology around the age of 2, other aspects of temporal language, such as temporal adverbs, prepositions, and conventional time units, are mastered much later (Nelson, 1996; Shatz, Tare, Nguyen, & Young, 2010; Valian, 2006; Wagner, Swensen, & Naigles, 2009). Interestingly, many young children will use time words productively without fully grasping their meanings. For example, a child might say *after naptime* to refer to some time in the future or use *yesterday* to describe an event in the past. This pattern has been observed for both relational terms, like *yesterday* and *after*, and terms encoding temporal units, like *hour* or *year* (Harner, 1975; Nelson, 1996; Shatz et al., 2010). These errors suggest that children have parsed the time word, understand its usage, and have identified it as a temporal term, but have not yet figured out the exact concept to which it maps.

The use of temporal terms to organize discourse presents additional challenges that children do not master until after the age of 9 (Berman & Slobin, 1994). Young children initially give descriptions organized around individual events. By 5 years, they produce narratives that link events in the order that they occurred, and employ connectives like *and then* and *after that* (Berman & Slobin, 1994). The use of more complex devices, which describe overlapping events or allow events to be presented out of their original order, increases gradually during middle childhood (Berman & Slobin, 1994; Hickmann, 2003).

These two patterns, cross-linguistic variability and a prolonged developmental trajectory, suggest that there might be a cultural and historical component to the development of temporal language. Historical linguist Guy Deutscher has argued that there is evidence for precisely this kind of trajectory in written texts from ancient languages (Deutscher, 2000, 2005). In the oldest Hittite and Babylonian texts, events are nearly always described in the order in which they occurred. Deutscher argues that the languages lacked true subordination, and lacked the temporal conjunctions that would be needed to mark relations like *before*, *after*, or *while*, and for this reason the writers had to rely on temporal iconicity, placing events in their true order. This example serves as the empirical centerpiece of Deutscher's (2005) argument that language is largely a cultural invention. On the face of it, his analysis suggests that the cultural forces that shape languages operate on the time scale of millennia. All biological adaptations for language must have been in place at least 70,000 years ago, the latest plausible date for the spread of anatomically modern humans from Africa (Cann, Stoneking, & Wilson, 1987). Our records of written language go back less than 5000 years. Thus, if we take this evidence at face value, there would seem to be a gap of more than 65,000 years (over 3000 generations) between the evolution of language and the emergence of a rich system of temporal conjunctions.

The study of creoles further complicates the picture. Creoles are young languages that may have their origins in the pidgins that form between speakers of different languages with a need to communicate. Over generations of use, a native creole language emerges. The correct characterization of tense, mood, and aspect marking (TMA) in creoles is controversial (see Singler, 1990). Bickerton and others have proposed that the TMA systems of creoles follow a standard pattern, where tense, mood, and aspect are expressed by a limited set of preverbal elements, which are placed in a consistent order: tense, mood, aspect, and then the main verb (see Bickerton, 1974, 1981, 1984; Muysken, 1981; Singler, 1990). Bickerton (1981) used this observation to motivate his Language Bioprogram Hypothesis (LBH). Other linguists have disputed this analysis, noting that some creoles fail to show this pattern of TMA marking (see Bakker, 2008; Bakker, Post, & van der Voort, 1995; Singler, 1990). Gil (2012) observed that in a sample of 76 creoles, TMA marking is obligatory only in 6 (8%), while it is obligatory in 491 of 868 non-creole languages (57%). The scarcity of obligatory TMA marking in creoles is argued to reflect their status as young languages, the implication being that they have not had sufficient time to develop it (Gil, 2012). Relevant to the current study, an additional issue is the degree to which the TMA system in a creole may have changed over time, making it difficult to determine the early system of marking solely on the basis of the current system (Singler, 1990).

The developmental data and historical patterns suggest that it would be useful to distinguish the types of temporal language that emerge early in language creation from those that might emerge later. Language production entails an inherent temporal structure, where uttering a stream of speech or signs occurs over time. As such, there may not be any convergence required for a new language to express simple temporal relations such as sequences of

<sup>2</sup> Note that English has no marker of present tense. The third person *-s* suffix is typically interpreted as conveying present tense, and is sometimes referred to as non-past.

events. A speaker or signer may indicate the temporal order of linearly-organized events simply by relying on the order of elements in the utterance, as in “*Veni, vidi, vici*,” or *I came, I saw, I conquered* (see Jakobson, 1960). On the other hand, to clearly express more complex temporal relations (e.g., “Before the man could go to the store, his daughter had to shovel the driveway because it had snowed the previous day”) a language must develop additional linguistic devices, such as tense markers, aspectual verbs, temporal connectives, and, in sign languages, simultaneous constructions. As such, a new language may be slower in converging on stable ways of expressing more complex temporal distinctions.

In the current study, we examined the emergence of temporal language in three sequential age cohorts of NSL users. The *first cohort* of signers, now in their forties, entered the community in its first decade, and the language began to emerge among them. The *second cohort*, now in their thirties, entered the community in its second decade, building on the language of the first. The *third cohort*, now in their twenties, represents the third decade in the history of NSL. By comparing the three cohorts, we can see how the expression of temporal relations has changed over the course of the early emergence of NSL. If a given temporal concept is readily available to individuals and can be quickly mapped to a linguistic device, we might expect to see that device emerge in the first cohort of Nicaraguan signers. Alternatively, if a temporal concept is challenging to grasp or if its particular linguistic form is difficult to converge on, we might expect to find differences across the groups with the relevant devices emerging only in the second or third cohort. Finally, if a given linguistic strategy requires a long period of historical evolution, it should be absent from the signing of all three groups.

In the present study, participants from each of the three cohorts described temporal events in a referential communication task. We looked at how successful signers were at imparting relevant information about time to a peer from within their cohort, and whether there were differences in the linguistic devices used by members of the three cohorts to describe two kinds of temporal stimuli: (1) temporal order events, which are sequences of actions that could in principle be effectively described using a linear order strategy and (2) temporal envelope events, in which the temporal relationship between the two events is something other than a simple sequence, such as simultaneity, co-termination, and containment.

## 2. Experiment 1

### 2.1. Method

#### 2.1.1. Participants

The participants in this study were 26 deaf Nicaraguan signers who were exposed to the emerging sign language by the age of 6 years (Table 1). Nine of the participants entered the signing community before 1983, and are referred to as first-cohort participants. Ten participants entered the community between 1986 and 1990, and are referred to as second-cohort participants. Seven participants entered the community between 1993 and 1998, and are referred to as third-cohort participants.

#### 2.1.2. Stimuli

Two sets of video stimuli were created: the Temporal Order set, and the Temporal Envelope set. The Temporal Order set included three sequences, each made up of four brief videoclips of events involving a single actor in a single location, engaged in four different activities. For example, one sequence presented a woman hanging a picture, drinking from a water bottle, buttoning a coat, and skipping. The action events within each of the sequences had no causal or conventional relationship to one another, to ensure

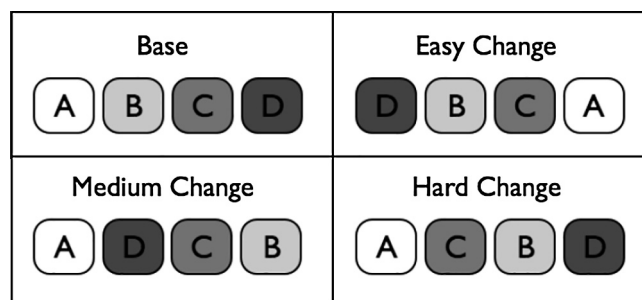
**Table 1**  
Participant demographics.

	Mean age in years	Range of age in years	Mean age of entry	Range of age of entry in years
Cohort 1	41.44	36–47	4.04	3.1–5.7
Cohort 2	30.50	28–33	4.13	3.1–5.3
Cohort 3	22.57	20–25	4.00	2.1–5.5

that participants would encode the sequence as four separate events, rather than as components of a single larger event. Each sequence had a base order, randomly chosen, for the four individual action events, as well as three alternative sequences, where the order of the action events was changed from the base version (e.g., switching the first and last action events from the above example: a woman skipping, drinking from a water bottle, buttoning a coat, and hanging a picture). Each trial included a target sequence and a variant sequence, which differed only in the order of the events presented. The particular order of events that was designated the target sequence to be described was counterbalanced across trials (i.e., the target sequence was not always the base version).

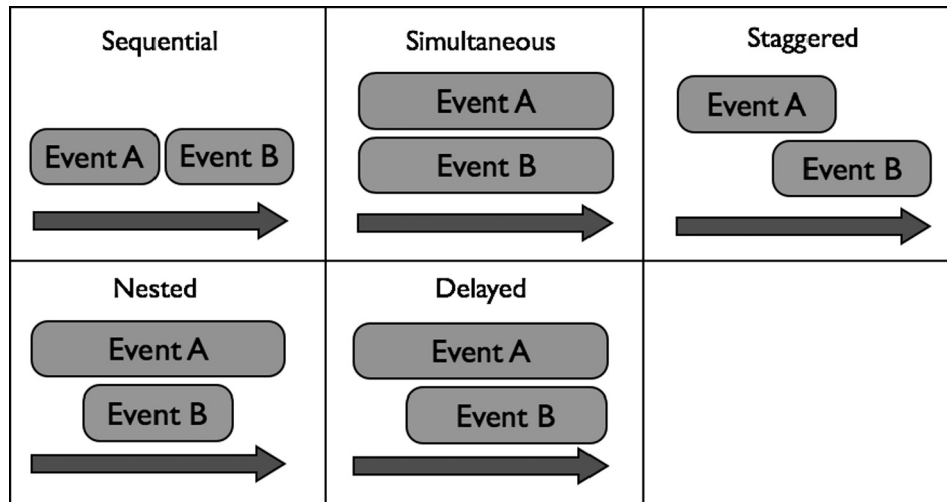
For each base sequence of four different action events, there were three types of changes made to the ordering of the actions, generating four different orderings of the events in the sequence. Not all changes to the ordering were equally salient or easy to detect. For instance, due to primacy and recency effects, the difference between two versions of a sequence where the first and last actions are switched (in Fig. 1, Base vs. Easy Change), is more salient than the difference between two versions of a sequence where the actions in the middle are switched (in Fig. 1, Base vs. Hard Change). For this reason, we counterbalanced these two types of temporal contrasts for the Temporal Order stimuli. Specifically, two versions of each trial were created (with different orders of targets and variants) for each of the three event sequences, and each was assigned to a different list (see Appendix A). Consequently, each list had one Base vs. Easy Change trial, one Base vs. Medium Change trial, and one Base vs. Hard Change trial.

The second set of stimuli, the Temporal Envelope items, portrayed two unrelated action events within a single videoclip (performed by either a single actor or two actors). Our envelope contrasts are defined by their coarse temporal properties (when one event ends and the other begins) without regard to the identity of the individual events (e.g., eating or spinning), which clearly differ in their temporal fine structure. For example, one event pair presented a woman spinning on a seat, next to a man walking back and forth. There were five such event pairs, each with five possible variants, depending on the temporal relations between the two events (see Fig. 2 for contrasts). In each list, two variants of each event pair were presented, such that any given contrast in



**Fig. 1.** Temporal order contrasts. The letters A–D represent the four individual action events performed by a single actor (e.g., clapping). On each trial, participants saw the base version of a sequence and one of the three alternative variants. The sequence (base or variant) designated as the target to be described was counterbalanced across trials.





**Fig. 2.** Temporal envelope contrasts. The letters A and B represent two distinct events, performed by either a single actor or two different actors. In each trial, participants saw two versions of the same pair of events, so that the two clips within the trial differed only in the temporal relations between the events.

temporal relations was presented only once in a list, and no particular variant of a given event pair appeared on both lists (see Appendix A). Importantly, with the Temporal Envelope stimuli, the temporal contrast between the two variants could not be captured by referring to only their relative starting moments; in other words, one could not successfully distinguish the stimuli by indicating only which event began first, and which began second.

Thus each list consisted of a total of eight different trials, three from the Temporal Order stimuli and five from the Temporal Envelope stimuli (see Appendix A for list of contrast pairings).

### 2.1.3. Procedure

We employed a referential communication task (see Yule, 1997). Participants were paired with a member of the same cohort, with one participant assigned to the role of communicator and one to the role of recipient. Each pair of participants completed one of two lists (List A or List B). If there was sufficient time in the session, the participants then switched roles and completed the other list (after a short break). Eight pairs completed both lists, and five completed just one.

The two participants viewed the same video sequences, at the same time, on separate laptop computers. The communicator was seated approximately 12 feet from the camera, facing the recipient, who was seated next to the camera. For each trial, two movies appeared on the screen as still frames, side by side, with the one on the left labeled “A” and the one on the right labeled “B.” One movie would expand to fill the screen, play, and then return, stopped, to its original size. The other movie would then expand, play, and return to its original size. At the end of the second movie, a red box appeared around the target movie on the communicator’s screen only. Participants were allowed to replay the movies if needed.

The two movies within a trial were always drawn from the same base event, and depicted different sequences or different types of temporal envelopes, depending on the contrast type. The communicator was asked to describe the target movie to the recipient. A camera located next to the recipient captured this description for later analysis. The recipient, who had seen the same two videos as the communicator, was asked to choose the movie that the communicator had described by signing the letter corresponding to the movie (A or B). The communicator or the experimenter then repeated the recipient’s choice to the camera for coding offline.

### 2.1.4. Coding and scoring

Success on the referential communication task was scored based on whether the recipient selected the correct target movie. In addition, the signed production data were coded by the first author, a fluent signer of ASL with 7 years of research experience with NSL. The coding scheme was designed to capture the temporality markers that have been observed in other languages (e.g., lexical items), as well as modality-specific devices for marking temporal information in sign languages (e.g., simultaneous constructions). Specifically, we focused on the use of three devices evident in the data: ordinal numbers, lexical items, and the dual use of hands (Figs. 3–5).

The first device, ordinal numbers, was coded as a positive if the signer used numbers to indicate the sequence of the events (Fig. 3). Any and all use of numbers or use of fingers to indicate the order of events was coded as an instance of an ordinal number. For instance, signers could mark the temporal order by indicating that one action happened *first*, and then another action *second*, and another action *third*. The second device, lexical items, was coded as positive if the signer made use of any signs, such as temporal adverbs and prepositions (NEXT, WAIT, CONTINUE, STOP<sup>3</sup>), that describe temporal relations or the onset or offset of actions (Fig. 4). The final device, the dual use of hands, was coded only for the Envelope events. This device was coded as positive if the signer employed both hands to set up a temporal contrast (Fig. 5). For instance, signers could depict one action using one hand, a different action using the other hand, and indicate the temporal overlap of the two actions through the onset of the two hands’ movements (e.g., two hands moving in synchrony vs. one hand moving first). Note that this particular linguistic device can be used only for events with two actors, namely, the Envelope events, each represented on a hand. For all three devices, we coded only whether that device was used for each description, not the frequency with which it appeared. In trials where the signer used multiple devices to describe a single event, each type of device used was coded as present.

## 2.2. Results

We conducted two kinds of analyses comparing the three cohorts. The first assessed communicative success in the

<sup>3</sup> English glosses for signs appear in SMALL CAPS.



**Fig. 3.** The use of ordinal numbers as a device to convey temporal information about an Order event in NSL. In the first panel, the signer signs *SECOND*, followed by a short description of the action in the second panel. In the third panel, the signer signs *THIRD*, followed by a short description of the action in the last panel.



**Fig. 4.** The use of lexical items as a device to convey temporal information. Use of this device was seen with both Order and Envelope events in NSL.



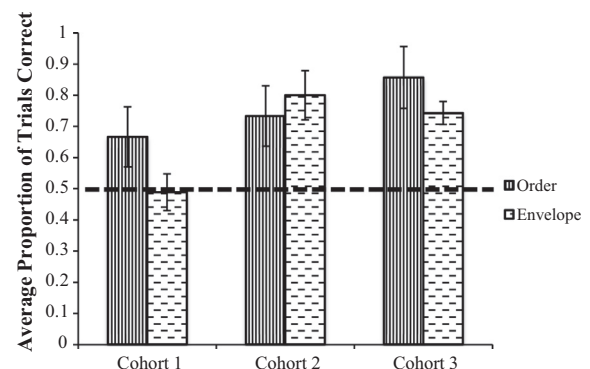
**Fig. 5.** The use of dual hands as a device to convey temporal information about a Nested event in NSL. In the first panel, the signer produces *SPIN* with his left hand, which is the action of the first character (a woman). In the second panel, the signer continues to sign *SPIN* with his left hand but also uses his right hand to sign *WALK*, signaling the onset of the action of the second character (a man). In the third panel, the signer signs *STOP* with his right hand, indicating the end of the man's walking. In the final panel, the signer signs *STAND* with his right hand, keeping it stationary, indicating that the man is standing, while continuing to sign *SPIN* with his left hand, indicating that the woman is still spinning.

referential communication task. The second explored the devices that were used to convey temporal information.

### 2.2.1. Communicative success

To determine whether there were differences in the cohorts in their ability to communicate about temporal contrasts, we analyzed the proportion of trials in which the recipient selected the correct video (see Fig. 6). For the pairs of participants who completed both lists, there was no effect of order on success (71.53% communicator first vs. 68.75% communicator second); we therefore excluded the variable of order from subsequent analyses.

The data were submitted to logistic mixed effects regression models with item and subject as random effects and with correct and incorrect responses entered as 1 and 0, respectively. All reported analyses coded cohort using two dummy variables, with the first cohort (the signers who entered the community prior to 1983) 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. The model with cohort as a predictor performed significantly better than the model without ( $F(3,5) = 7.499$ ,  $p = 0.024$ ), indicating that there were differences in communicative success across cohorts. We then



**Fig. 6.** Success on referential communication task. Error bars represent standard error.

conducted pairwise comparisons to determine where the difference lay. There was a significant difference between the first cohort and the second cohort ( $p = 0.007$ ), and between the first cohort and the third cohort ( $p = 0.015$ ), but not between the second cohort and the third cohort ( $p = 0.981$ ). Moreover, second- and third-cohort signers performed significantly above chance (second cohort:

Mdn = 6.5, Wilcoxon Signed-Rank Test,  $Z = 2.678$ ,  $p = 0.007$ ; third cohort: Mdn = 6,  $Z = 2.401$ ,  $p = 0.020$ ), while the first-cohort signers did not (Mdn = 5 out of 8,  $Z = 1.350$ ,  $p = 0.219$ ).

To determine whether both types of temporal contrasts showed the same pattern across cohorts, we conducted separate analyses of the two stimulus types. Logistic mixed effects models were constructed for the Order trials and Envelope trials, each with item and subject as random effects. Again, we compared two models for each trial type, one with cohort as a predictor and one without cohort as a predictor, with the first cohort as the baseline. There was no significant effect of cohort on performance with the Order trials ( $F(3,5) = 2.094$ ,  $p = 0.351$ ). However, there was an effect of cohort in the Envelope trials ( $F(3,5) = 8.382$ ,  $p = 0.015$ ). Pairwise comparisons revealed that the difference between the first cohort and the second cohort was significant ( $p = 0.003$ ), as was the difference between the first cohort and the third cohort ( $p = 0.049$ ), whereas the difference between the second and third cohorts was not significant ( $p = 0.403$ ). In other words, signers from all three cohorts were similarly able to convey the temporal information in the Order trials. In contrast, the second and third cohort signers were more successful in communicating about the Envelope trials than the first cohort signers. Signers from all three cohorts were above chance for the Order trials (Table 2). In contrast, for the Envelope trials, while the second- and third-cohort signers performed well above chance, the first-cohort signers did not (Table 3).

### 2.2.2. Devices used to convey temporal information

We analyzed the use of the three linguistic devices: lexical items, ordinal numbers, and for the Envelope events only, the dual use of hands. When signers did not use one of the three devices, they primarily relied on linear order of mention (for the Order trials), or switched back and forth between descriptions of the two events without providing information about their temporal overlap (for the Envelope trials).

Because the stimuli for the Order and Envelope trials were designed to elicit different devices we analyzed them separately (Figs. 7 and 8, respectively). For each device we constructed separate logistic mixed effects models, with the trial coded as 1 when the device was present and 0 when it was absent. For the linear order device analysis, the dependent variable, signing the event in veridical order, was coded as a 1 if the signer mentioned all four events in the order in which they occurred in the stimulus, and a 0 if they produced some other ordering of signs. To test for cohort effects, in each analysis we compared the model where cohort was included as a predictor to the model where it was not. If the model with cohort as a predictor performed better, we conducted follow-up pairwise comparisons to determine where the difference lay.

**Table 2**

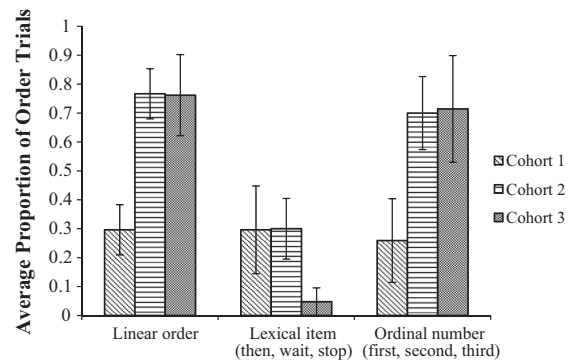
Results of the Wilcoxon Signed-Rank Test comparing performance on order trials to chance.

	Median	Z	p-value
Cohort 1	2 out of 3	2.387	0.031
Cohort 2	2 out of 3	2.521	0.014
Cohort 3	3 out of 3	2.377	0.031

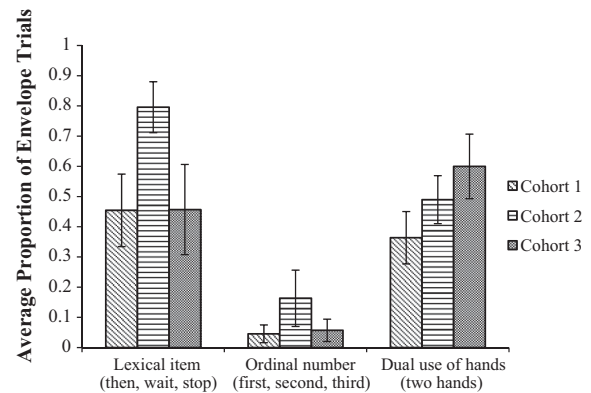
**Table 3**

Results of the Wilcoxon Signed-Rank Test comparing performance on envelope trials to chance.

	Median	Z	p-value
Cohort 1	2 out of 5	−0.250	0.973
Cohort 2	4.5 out of 5	2.44	0.014
Cohort 3	4 out of 5	2.46	0.017



**Fig. 7.** Proportion of all Order trials in which a given linguistic device was used. Error bars represent standard error.



**Fig. 8.** Proportion of all Envelope trials in which a given linguistic device was used. Error bars represent standard error.

For Order events, we first determined whether signers from all three cohorts communicated the order of the events veridically. Logistic mixed effects models were constructed for the Order trials, with item and subject as random effects and the first cohort as the intercept (Table 4). There was an effect of cohort on correct linear order ( $F(3,5) = 12.122$ ,  $p = 0.002$ ). Follow-up pairwise comparisons showed a significant difference between the first and second cohorts ( $p < 0.001$ ) and between the first and third cohorts ( $p < 0.001$ ), but not between the second and third cohorts ( $p = 0.970$ ), suggesting that first-cohort signers were less likely than the other two groups to describe all four events in veridical order. Next, we looked at whether signers from all three cohorts signed the majority (at least three) of the events in veridical order. Logistic mixed effects models were constructed, and we observed no effect of cohort ( $F(3,5) = 2.334$ ,  $p = 0.311$ ). Thus, although the first-cohort signers do not produce a veridical order of signs for

**Table 4**

Results of the mixed-effects logistic regression predicting use of device by cohort for order trials. Cohort 1 represents the intercept.

Device	Predictor	b	Wald's z	p-value	Odds ratio
Linear order	Cohort 1	−1.047	−1.853		
	Cohort 2	2.490	3.265	0.001	9.200
	Cohort 3	2.483	2.938	0.003	27.017
Lexical item	Cohort 1	−2.010	−1.795		
	Cohort 2	0.441	0.298	0.766	1.554
	Cohort 3	−2.821	−1.175	0.240	0.060
Ordinal number	Cohort 1	−8.611	−1.147		
	Cohort 2	17.171	1.726	0.084	$2.865 \times 10^7$
	Cohort 3	17.225	1.458	0.145	$3.025 \times 10^7$



all four events as often as second- and third-cohort signers, they are still providing considerable information about the order of the events in the sequence.

Separate logistic mixed effect models were constructed for the other two devices, lexical items and ordinal numbers. There was no effect of cohort on the use of lexical items to mark temporal information (first cohort: 30%, second cohort: 30%, third cohort: 5%;  $F(3,5) = 3.500$ ,  $p = 0.174$ ). However, there was a significant effect of cohort on the use of ordinal numbers to convey information about the sequence (first cohort: 26%, second cohort: 70%, third cohort: 71%;  $F(3,5) = 15.068$ ,  $p < 0.001$ ). Follow-up pairwise comparisons revealed a significant difference between the first and second cohorts ( $p = 0.001$ ) and between the first and third cohorts ( $p = 0.001$ ), but not between the second and third cohorts ( $p = 0.913$ ). Thus, the signers from the three cohorts do not reliably differ in their use of lexical items when communicating about the temporal order of events. However, second- and third-cohort signers use ordinal numbers for this function more than first-cohort signers.

Next, we examined whether the use of ordinal numbers affected communicative success. A separate logistic mixed effects model was constructed for the Order trials, with item and subject as random effects. The use of ordinals was entered as a predictor variable, with the use of ordinals coded as 1, and the absence as a 0, while communicative success (whether the recipient picked the correct movie) was the dependent variable. The difference between the intercept (no use of ordinal numbers) and the use of ordinal numbers was not significant ( $Z = 1.042$ ,  $p = 0.297$ ), suggesting that use of ordinals did not improve comprehension. Then, we looked at whether signing the Order events in the veridical linear order was facilitated by the use of ordinals. Again, the use of ordinals was entered as a predictor variable, with the use of ordinals entered as 1, and the absence as a 0, and signing events in the veridical order as the dependent variable. Item and subject were treated as random effects. The difference between the intercept (no use of ordinal numbers) and the use of ordinal numbers was significant ( $Z = 2.977$ ,  $p = 0.003$ ), suggesting that while the use of ordinal numbers does not significantly improve communicative success, it may be advantageous for the producer, who is then more likely to successfully sign the events in veridical order. Another possibility is that signing the events in veridical order facilitates the use of ordinal numbers. We return to this finding in the discussion.

For the Envelope events, the analyses of device use (Fig. 8) provided insight into the differences that we had found between the cohorts in communicative success (Fig. 6, Table 5). Ordinal numbers are ill-suited for conveying envelope information, and unsurprisingly, they were rarely used, with no differences across cohorts ( $F(3,5) = 2.387$ ,  $p = 0.303$ ). However there was an effect of cohort on the use of lexical items to describe the temporal information ( $F(3,5) = 6.812$ ,  $p = 0.033$ ). The use of lexical items increased from the first cohort to the second cohort ( $p = 0.002$ ) and then decreased

from the second cohort to the third cohort ( $p = 0.001$ ). As a result, there was no difference between the first and third cohorts ( $p = 0.624$ ). For the third device, the use of dual hands (unique to the Envelope trials), we observed a marginal effect of cohort ( $F(3,5) = 5.018$ ,  $p = 0.081$ ), which was driven by the difference between the first cohort and the third cohort ( $p = 0.021$ ). The difference between the first cohort and the second cohort was not significant ( $p = 0.117$ ), nor was the difference between the second cohort and the third cohort ( $p = 0.354$ ). This suggests that the use of dual hands, unlike use of lexical items, has increased gradually as the language has matured.

### 2.3. Discussion

The communication of temporal information differed systematically across the three cohorts of signers. On the Order trials, most of the first-cohort signers simply described the events (or most of the events) in the order in which they occurred. This strategy allowed their partners to identify the correct sequence most of the time (67% of the Order trials).<sup>4</sup> However, on the Envelope trials, where the target could not be distinguished from a variant by a sequential description of events, the first-cohort signers failed to consistently encode the temporal properties of the events, and the recipients performed at chance.

The second- and third-cohort signers were able to successfully communicate about both the order of events and their relative timing. On the Order trials, they supplemented the sequential signing strategy with the use of ordinal numbers, which appeared to help them remember the order of all four events. On the Envelope trials, they used two different kinds of devices – lexical items and the dual use of hands – to convey temporal relations. The use of lexical items peaked with the second cohort, while the dual use of hands continued to increase in the third cohort. Second-cohort signers frequently used two different kinds of devices in a single Envelope trial. In contrast, third-cohort signers generally used a single device that was evidently sufficient to convey the temporal distinction successfully.

The poor performance of the first-cohort signers in the referential communication task is compatible with two explanations. First, signers from the first cohort may fail to describe the temporal relations in the Envelope stimuli because they fail to notice these differences, or fail to conceptually encode them in a format that would allow them to accurately remember the two clips long enough to respond. Such difficulties might be expected under a strong version of the Whorfian hypothesis, in which linguistic encoding of a distinction is necessary for systematic conceptual access. Alternatively, the first-cohort signers may accurately perceive and remember the temporal distinctions in the envelope videos but lack the linguistic resources needed to convey this information to their partner. Experiment 2 tests the first of these hypotheses.

The use of ordinal numbers for the Order trials was unexpected. Because it is possible to communicate the sequence simply by signing the events in veridical order, we had not expected to see the use of numbers in this task. The results of the Experiment 1 suggest that first-cohort signers are less likely to use this device. The task as designed did not require the use of ordinal information to distinguish between the referents, so the difference between the older and younger signers could reflect stylistic preferences,

**Table 5**

Results of the mixed-effects logistic regression predicting use of device by cohort for envelope trials. Cohort 1 represents the intercept.

Device	Predictor	<i>b</i>	Wald's <i>z</i>	<i>p</i> -value	Odds ratio
Lexical item	Cohort 1	0.510	0.459		
	Cohort 2	3.600	2.159	0.031	36.517
	Cohort 3	−0.382	−0.242	0.809	0.682
Ordinal number	Cohort 1	−10.173	−1.742		
	Cohort 2	0.966	0.132	0.895	2.627
	Cohort 3	−0.596	−0.060	0.952	0.551
Dual use of hands	Cohort 1	−2.482	−1.996		
	Cohort 2	1.817	1.522	0.128	6.153
	Cohort 3	2.977	2.301	0.021	19.631

<sup>4</sup> Note that depending on the distractor movie if the producer signed only two events in the veridical order, the comprehender might still be able to choose the correct video. For example, in the case of an Easy Change contrast, the first and last events of the target are swapped in the distractor video (A-B-C-D and D-B-C-A). If the producer correctly describes A first, the comprehender could still select the target video.



perhaps for redundancy, or precision. Experiment 3 uses a task designed to elicit ordinal numbers to explore this use of ordinal numbers in more detail.

### 3. Experiment 2

To succeed in the referential communication task participants must be able to detect the temporal differences between the paired videos and convey that information to a partner. We expected that signers from all three cohorts would be able to detect these differences, and that any differences in their performance would be due to variation in their ability to linguistically encode the distinctions. To verify this, in the year following Experiment 1, we administered a change-detection task to a subset of the signers who had participated in the Referential Communication task.

#### 3.1. Method

##### 3.1.1. Participants

The participants in this study were four signers: the two first-cohort signers (ages 42.3 and 45.8) and the two second-cohort signers (ages 31.7 and 32.4), who had had the lowest performance for their cohort in the role of the communicator in the referential communication task (Cohort 1 mean: 38%, Cohort 2 mean: 63%).

##### 3.1.2. Materials and procedure

The Order and Envelope videoclips from Experiment 1 were used to construct a change-detection task. On each trial, participants were shown two movies and were asked to indicate whether they were the same as each other, or different. Participants saw a total of 14 items, with 6 Order trials and 8 Envelope trials, drawn from the two lists used in the referential communication task. Half of the Order trials and half of the Envelope trials (7 trials total) were randomly designated as change trials, in which the second movie differed from the first in its temporal properties (as in the targets and distractors in Experiment 1). The other half of the items were no-change trials, in which the second movie was identical to the first. As in Experiment 1, participants were allowed to replay the movies if needed.

#### 3.2. Results

Our subset of signers from both cohorts performed equally well on the change-detection task (Table 6). There was no difference between the first- and second-cohort signers on the Order trials (first cohort mean: 92%; second cohort mean: 83%;  $p = ns$ ) or the Envelope trials (first cohort mean: 81%; second cohort mean: 88%;  $p = ns$ ).

#### 3.3. Discussion

Both the first- and second-cohort signers performed well on our task, and they were equally able to detect the differences in our temporal stimuli. This finding indicates that the chance level performance by first-cohort signers on the referential communication task is unlikely to be caused by an inability to distinguish the

paired contrasts from each other, though caution should be exercised in interpreting this finding, as our sample size was small. Instead, the change across cohorts in successful performance on the referential communication task appears to stem from differences in their ability to express temporal information by using linguistic devices such temporal lexical items or the dual use of hands. We take up this point again in the general discussion.

### 4. Experiment 3

In Experiment 1, we found that the signers from the later cohorts often used numbers to mark temporal order, unlike signers from the first cohort. This was surprising because prior work demonstrates that the first-cohort signers have number signs (Katseff & Senghas, 2004) which they can use reliably to encode the cardinal value of sets of objects in both comprehension and production tasks (Flaherty & Senghas, 2011). In addition, the concepts of space, time, and number are linkable by an underlying representation of magnitude that may support generalization across these dimensions. When processing spatial and temporal, or spatial and numerical information, temporal and numerical representations are affected by spatial information (Casasanto & Boroditsky, 2008; Dehaene, Bossini, & Giraux, 1993). Evidence from adults' performance on a dual-task experiment suggests that time and number are linked. Performing mental arithmetic interferes with judgments of duration, and making duration judgments interferes with mental arithmetic (Brown, 1997). Developmental work shows that neonates can relate number and duration to spatial length when the dimensions vary in the same direction, namely both increasing or decreasing (de Hevia, Izard, Coubart, Spelke, & Streri, 2014).

Thus, given the relation between underlying representations of time and number, we might have expected that the signers from all three cohorts would be apt to use number signs in the temporal order task. However, the first-cohort signers seldom used numbers when describing these ordered events. While this strategy was not necessary for performing the task, since the distinctions could be conveyed by signing the events in veridical order, it was still useful. When numbers were provided, the ability to produce a veridical order was improved.

The results of Experiment 1 raise the possibility that cardinal and ordinal uses of numbers emerged at different times in the development of NSL. A cardinal number encodes the number of individuals in a set, picking out the set as a group. In contrast, an ordinal number encodes the position of an item in a spatial or temporal sequence, picking out a singleton from a set. All of the prior work on number in NSL and homesign (Coppola, Spaepen, & Goldin-Meadow, 2013; Spaepen, Coppola, Spelke, Carey, & Goldin-Meadow, 2011) has looked at cardinal numbers as applied to sets of physical objects. It is believed that ordinal numbers arose later in the historical evolution of spoken languages: ordinal numbers are often morphologically derived from cardinal numbers, but cardinals are never derived from ordinals. About 10% of languages with cardinal numbers lack ordinal forms, and fail to use cardinal numbers in ordinal contexts (Stolz & Veselinova, 2013). The development of NSL may provide the opportunity to observe this process in real time.

Ordinal numbers also emerge relatively later in individual children's language development, though this could reflect several different properties of their use (Colomé & Noël, 2012). First, understanding ordinality may involve a violation of one principle underlying cardinality, where the order in which you count items does not affect the final value of the set (Wiese, 2007). Second, ordinality may be a more complex notion for children to grasp because a set only has one cardinal value, but multiple ordinal val-

**Table 6**  
Percent correct on change-detection task.

Cohort	Participant	Order (%)	Envelope (%)
1	A	100	75
1	B	83	88
2	C	83	100
2	D	83	75

ues. In other words, when a set of four objects, say horses, are lined up, the cardinal value of that set is *four*, but each horse has a different ordinal position: *first*, *second*, *third*, and *fourth* (or *last*). Finally, ordinal words, with the possible exception of *first* and *last*, are far less frequent than cardinal numbers (e.g., *third* is less frequent than *three*) in children's input (e.g., Colomé & Noël, 2012; Miller, Major, Shu, & Zhang, 2000).

There are three possible reasons for the observed difference in the use of ordinal numbers across the cohorts. The first possibility is that the difference is an artifact of our task, which was not explicitly designed to probe ordinality. Perhaps the first-cohort signers do not use ordinal numbers when they are not clearly relevant, but can use them in a more transparent counting task. The second possibility is that the first cohort has difficulty using numbers to order transient events, but is able to use them to order physical objects. The final possibility is that first-cohort signers have difficulty using numbers to express any kind of ordinal relations, perhaps because a new language is slower to converge on explicit markers of ordinal relations than it is to converge on markers for cardinal values.

In Experiment 3, we used a task that required the use of ordinal markers to identify the position of an object in a line. If the cohort difference was due solely to task demands, or to an inability to use ordinal numbers for events, then we would expect first-cohort signers to perform similarly to the later cohorts in this task. However, if the cohort difference reflects a change in the devices available to mark ordinal relations of any kind, then we should expect it to persist in this task. As a control, we included trials designed to elicit use cardinal numbers to ensure that all participants were able to use numbers to mark the cardinality of a set.

#### 4.1. Method

##### 4.1.1. Participants

Participants in this study were 26 Nicaraguan signers, 9 first-cohort signers (mean age = 41.44, range: 36–47), 9 second-cohort signers (mean age = 30.33, range: 28–33), and 8 third-cohort signers (mean age = 21.63, range: 20–24). All of the first-cohort and second-cohort signers and most of third-cohort signers (7 out of

8) had participated in Experiment 1 (one year earlier), and two of the first-cohort signers and two of the second-cohort signers participated in Experiment 2. All participants were exposed to NSL by 6 years of age.

##### 4.1.2. Materials and procedure

We adapted a task used by Colomé and Noël (2012) to test children's understanding of cardinal and ordinal numbers. Participants were shown a series of pictures (some with simple animations) and asked to describe what they saw. In our version of the task, each picture consisted of one to five items of the same kind arranged in a line. The objects were either animate (birds, bees) or inanimate (planes, cars), and had a clear front and back (defined by a face or the object's typical direction of motion). The objects all faced a single reference object (e.g., a tree) and thus this object defined the front of the line. The location of the reference object (far left or far right) was counterbalanced across items. During the practice trials, the experimenter took care to ensure that participants understood that the reference object defined the direction from which counting should begin (left to right or right to left). On the cardinal trials, participants either saw a set of stationary objects (Fig. 9) or an event in which a subset of objects moved in place (e.g., danced or bounced). On the ordinal trials, there were always at least three objects in the line, and one of the objects was singled out, either because it was brightly colored while the other objects were gray (Fig. 10), or because it performed some action (like moving towards the reference object) while the other objects were stationary.

Participants were asked to describe the pictures. However, if they did not spontaneously provide a cardinal number on cardinal trials or information about the ordinal position of the target object on ordinal trials, the experimenter would ask a follow-up question. For example, on a cardinal trial without any motion the experimenter would ask, "How many are there all together?" In contrast, on an ordinal color trial, the experimenter would point to the brightly colored object and ask questions like, "Where is the blue bird?" or "Which one is the blue bird?"

There were a total of 24 trials, 12 cardinal trials and 12 ordinal trials. Using two lists, List A and List B, trials were counterbalanced



Fig. 9. Cardinal trial. Participants described how many bicycles there were in the picture.

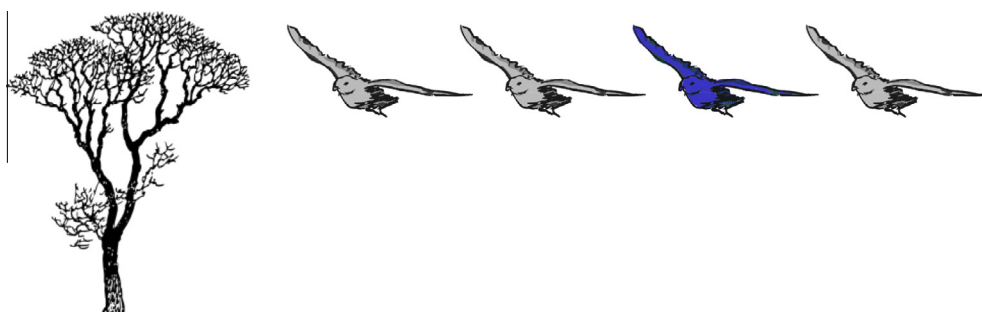


Fig. 10. Ordinal-object stimulus. Participants described which bird was blue. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

for whether the set of objects appeared in a cardinal or ordinal trial. The ordinal position of the target object (first, second, third, fourth, or fifth) was counterbalanced across items. A subset of trials were excluded from the analyses because they involved multiple objects engaged in an action, and it turned out to be unclear in the responses whether participants were indicating the cardinal value of objects that moved or the ordinal position of the objects that moved. After excluding those trials, there were 18 trials remaining in each list. In addition, the majority of participants were unable to see the motions the objects underwent in two trials in List B, and so those trials were excluded as well, yielding 34 trials for analysis.

#### 4.1.3. Coding

Signed descriptions of the cardinal trials were coded for whether signers indicated the cardinal value of the set using a number sign, and whether they provided the correct cardinal value. Descriptions for the ordinal trials were coded for whether the signer indicated an ordinal position (in some manner), and whether the ordinal position indicated was the correct one for the target object. Given the affordances of the visual-manual modality, there are multiple ways in which a signer can encode ordinality. We coded the ordinal trials for the presence of four devices: the use of *number signs* referring to the ordinal position, the use of *points-to-fingers*, the use of *points-to-space*, and the use of *classifiers*.

The first device is straightforward: in signed languages, like spoken languages (Stolz & Veselinova, 2013; Veselinova, 1997), some ordinal numbers can be derived from cardinal numbers (e.g., Liddell, 1997; Zeshan, 2003). In NSL, we have detected no morphological marker that differentiates ordinal from cardinal numbers. Thus any number sign produced on an ordinal trial was taken to be an ordinal number, and was coded as correct if it corresponded to the position of the target item relative to the reference object.

A response was coded as *points-to-fingers* when the signer used the fingers of one hand to represent the set of depicted items (which was always five or fewer), and then used the other hand to point to a finger representing the target object. Unless the signer gives an explicit indication of which finger represents the front (and thus the start of the count list), there are two possible interpretations of such a point. For instance, a point to the index finger when holding up four fingers could correspond either to the first position or the fourth position. We coded the signer's use of this device as correct if the signer's point picked out the correct item under either interpretation.

*Points-to-space* occurred when the participant established an ordered set of items in the signing space and then pointed to one of the established locations to indicate the target item. These responses were coded as correct when the space that was pointed to was the one that was associated with the target object.

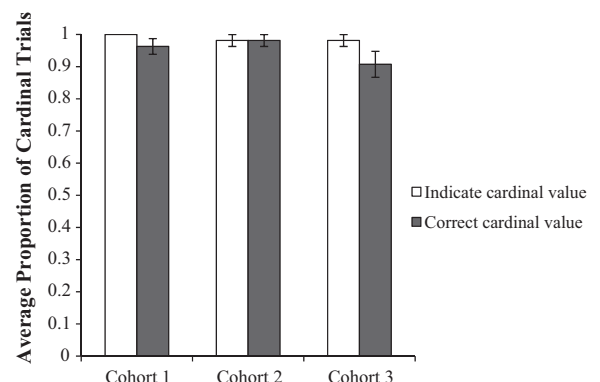
Classifier use also involves the establishment of a set of referents in the signing space, and the selection of one of these referents. In sign languages, classifiers express location, handling, and stative-descriptive information as well as motions of referents in the sign space. The placement and location of classifiers in the three-dimensional signing space in front of the signer provides information about the relationships between referents (see Emmorey, 2002 for a review). Due to the nature of our stimuli, which depicted animals and vehicles, the majority of the classifier handshapes we observed were entity/whole object, where the hand is used to represent the object as a whole. We coded use of this device as correct if the signer's use of a classifier picked out the correct target object.

## 4.2. Results

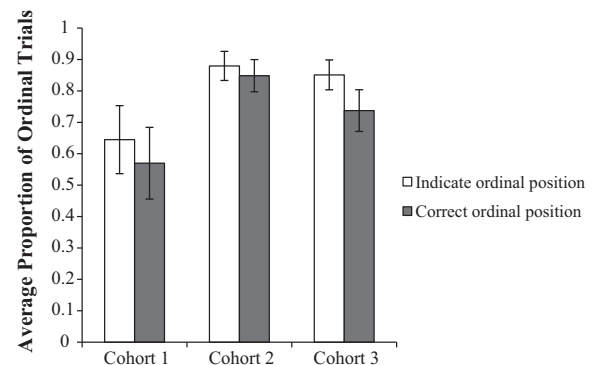
Our initial analyses focused on the proportion of trials in which the signers provided numerical information and the degree to which this information was accurate. Our secondary analyses looked at the specific devices that were employed. All of our analyses used logistic mixed-effects models with the same coding scheme employed in Experiments 1 and 2.

On the cardinal trials, the signers from all three cohorts consistently produced number signs that correctly conveyed the number of items in the set (Fig. 11). Thus, there were no significant differences between the cohorts in number use (second cohort:  $Z = 0.00$ ,  $p = 1.00$ ; third cohort:  $Z = 0.00$ ,  $p = 1.00$ ) or accuracy (second cohort:  $Z = 0.509$ ,  $p = 0.611$ ; third cohort:  $Z = -1.099$ ,  $p = 0.272$ ).

In contrast, on many of the ordinal trials, the first-cohort signers did not provide information about ordinal position, resulting in differences across the cohorts (Fig. 12). Specifically, first-cohort signers, as represented by the intercept, were less likely than second-cohort signers to indicate ordinal position (second cohort:  $Z = 2.107$ ,  $p = 0.035$ ) or to do so accurately (second cohort:  $Z = 2.385$ ,  $p = 0.017$ ). The differences between the first cohort (the intercept) and the third cohort were not statistically significant for indicating ordinal position (third cohort:  $Z = 1.703$ ,  $p = 0.089$ ) or for accuracy (third cohort:  $Z = 1.286$ ,  $p = 0.199$ ). There was also no significant difference between the second cohort and the third cohort for indication of ordinal position ( $Z = 0.431$ ,  $p = 0.667$ ) or accuracy ( $Z = 1.139$ ,  $p = 0.255$ ). We suspect that the results relative



**Fig. 11.** The first set of bars represents the proportion of cardinal trials in which participants provided a cardinal number sign, by cohort. The second set of bars represents the proportion of trials in which the cardinal value given was correct. Error bars represent standard error.



**Fig. 12.** The first set of bars represents the proportion of ordinal trials in which participants indicated an ordinal position, by cohort. The second set of bars represents the proportion of trials in which the ordinal position given was correct. Error bars represent standard error.



to the third cohort reflect the limited size of our sample and variability in the performance of the third-cohort participants, rather than any meaningful change in the language between the second and third cohort.

Our final analysis focused on the four specific devices that were used to indicate the ordinal position of the target object, and the degree to which their use changed across the cohorts (Fig. 13). Separate mixed effects models were constructed for the presence of each type of device. There were no significant differences across the cohorts in the use of ordinal numbers, points-to-fingers, and classifiers (Table 7). However, there was a significant difference between the first cohort and the second cohort, and between the first cohort and the third cohort, in use of points-to-space to indicate the ordinal position of the target object.

#### 4.3. Discussion

Three clear findings emerged from Experiment 3. First, the signers from all three cohorts consistently and accurately used number signs to convey cardinal value, confirming that they have signs for numerals, and they are able to use them to count the members of sets (Flaherty & Senghas, 2011). Second, while second-cohort signers provided accurate information about the ordinal positions of objects in arrays, first-cohort signers often did not do so (85% vs. 57%). This pattern is consistent with what we observed in Experiment 1, where first-cohort signers were less likely to explicitly mark the order of events. The results from Experiment 3 demonstrate that the cohort difference persists in a task where explicit ordinal information is necessary (rather than redundant), and where it is objects, rather than events, that are being ordered. This

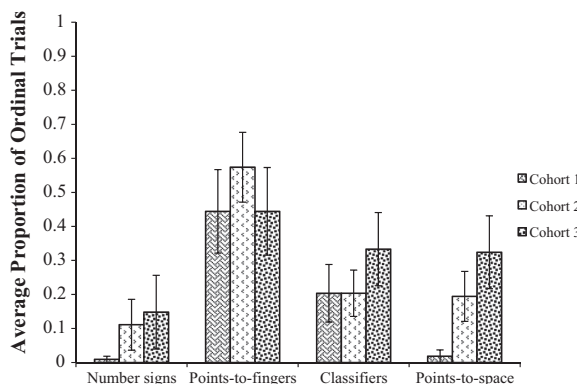


Fig. 13. Proportion of ordinal trials in which each linguistic device was used by each cohort. Error bars represent standard error.

Table 7

Results of the mixed-effects logistic regression predicting use of device by cohort. Cohort 1 represents the intercept.

Device	Predictor	<i>b</i>	Wald's <i>z</i>	<i>p</i> -value	Odds ratio
Number signs	Cohort 1	−7.874	−2.319		
	Cohort 2	2.219	0.573	0.567	9.200
	Cohort 3	3.296	0.872	0.383	27.017
Points-to-fingers	Cohort 1	−0.3169	−0.386		
	Cohort 2	0.8294	0.729	0.466	2.292
	Cohort 3	−0.1552	−0.135	0.892	0.856
Classifiers	Cohort 1	−2.4183	−3.248		
	Cohort 2	−0.029	−0.030	0.976	0.971
	Cohort 3	1.2425	1.303	0.193	3.464
Points-to-space	Cohort 1	−5.700	−4.194		
	Cohort 2	3.231	2.128	0.033	25.300
	Cohort 3	4.418	2.946	0.003	82.902

difference, however, is quantitative rather than qualitative: first-cohort signers are able to provide order information, using a variety of linguistic devices, even if they are inconsistent in doing so. Third, we found that all three cohorts used a variety of different devices to mark ordinal relations, with no clear preference for one device, though ordinal position is most often encoded spatially rather than through ordinal number signs. Only the use of points to space increased reliably in the second (and third) cohort. Taken together, these findings suggest that the consistent marking of ordinal relations emerges gradually in a new language.

## 5. General discussion

The emergence of a new sign language in Nicaragua offers us the opportunity to capture how a language is created, allowing us to address central questions in cognitive science: to what degree are the seeds of human language present in each individual human mind (Chomsky, 1968, 1975, 2000; Pinker, 1994); to what degree do these seeds require social context and transmission across individuals to become a natural language; and whether these social processes unfold over millennia as the cultural evolution hypothesis suggests (Deutscher, 2005; Tomasello, 1999; Tomasello et al., 1993). By looking at the emergence of temporal language in three sequential age cohorts of NSL, we hoped to disentangle the respective contributions of human cognition and repeated social transmission within a community of users, at least in this particular linguistic domain. Temporal concepts range in complexity, from simple, such as order (one thing happening after another), to more complex (one thing starting after another, but ending before the other ends). Given the prevalence of time in our everyday experiences, there are reasons to expect temporal language to emerge early in language creation. At the same time, the abstractness and complexity of time may create conceptual hurdles for the learner (Snedeker, Geren, & Shafto, 2012; Tillman & Barner, 2015) or make it more difficult for communities to quickly converge on effective linguistic devices.

We observed differences in how quickly effective ways to communicate about time emerge in NSL, depending on the kind of temporal relations entailed in an event. Signers from all three cohorts were well able to linguistically convey simple ordered events, but younger signers, those in the second and third age cohorts, outperformed older signers in describing events with more complex temporal relations.

### 5.1. Cohort differences in the referential communication task

The difference that we identified between cohorts in conveying complex temporal relations did not stem from a failure to detect the relevant temporal contrasts. If it had, we would have observed a corresponding difference between cohorts in change detection, and we detected no such difference. We recognize that one limitation of the current study is our small sample size. Even so, there are good reasons to think that these abilities are robustly present in all cohorts. First, we tested the participants who had the poorest performance on the communication task, and were therefore the most likely to have a memory or perceptual deficit. Second, the perceptual distinctions used in this task are ones that are available to infants and non-human animals (Bahrick, 1988; Chang & Trehub, 1977; Demany et al., 1977; Gardner et al., 1986; Lewkowicz, 2000). Accordingly, the cohort differences appear to reflect systematic differences in how frequently and effectively signers use emergent linguistic devices to convey temporal contrasts.

Further evidence for this interpretation comes from a pilot study that we conducted on the ability of first-cohort signers to understand the linguistic descriptions that had been generated

in Experiment 1. In this study we used a matching task, where participants saw a signed description from either a first-cohort signer or a second-cohort signer, and were asked to select between two movies that depicted the same base events but had contrasting temporal relations. The results from this preliminary work suggest that first-cohort signers perform better when shown descriptions produced by second-cohort signers, rather than by first-cohort signers, suggesting that they are able to make use of the richer linguistic descriptions provided by the younger signers. This, along with our finding here that there is no cohort difference in the ability to detect differences in temporal relations, suggests that the cohort differences in the referential communication task are due to differences in language production, not to differences in the comprehension or conceptual encoding of temporal relations. The implication is clear: While the cognitive understanding of temporality is evident in signers from all cohorts, it takes time, and at least two generation of signers, before the language converges on systematic and consistent ways of conveying this information.

### 5.2. The development of devices for encoding temporal order in NSL

When describing a sequence of events, first-cohort signers primarily rely on the order of signs to convey information about the order of the events. In contrast, second- and third cohort signers use ordinal numbers to mark the temporal order of the events. The drop in the use of lexical items to convey temporal order information as NSL passed from the second to the third cohort suggests that ordinal numbers may be emerging as the preferred device in the language for conveying the temporal order of arbitrary sequences.

Despite these cohort differences in linguistic descriptions, there was no difference among the three cohorts in their performance on the referential communication task. First-cohort signers were able to rely on just the order of signs within the utterance to successfully comprehend descriptions of temporal order, raising the question of why an alternative device such as the use of ordinal numbers to mark temporal order would ever emerge. Consider for a moment our finding that the use of ordinal numbers was associated with a greater likelihood of signing the four events in the correct order. This finding suggests three possible explanations. The first possibility is perhaps the least interesting: it may be that both factors are affected by some third variable (such as the effort needed for verbal encoding or momentary changes in attention) but not closely related to one another. The second possibility is that correct ordering facilitates the use of ordinal numbers. Inaccurate ordering is information that is available to us in our analysis but is not, in any obvious way, available to the signer (who presumably is unaware of any inaccuracy until after the trial ends). Thus, the mechanism by which it could influence communication is murky, making this possibility seem unlikely. The third, and perhaps most sensible account is that ordinal numbers serve as memory placeholders, allowing for better recall of events and their order within a sequence. Thus, while ordinal numbers may not substantially improve addressees' comprehension, at least in our task, they may help language producers in the retrieval and description of longer events.

### 5.3. The development of devices for encoding of temporal overlap in NSL

The clearest difference in our data across the cohorts of NSL signers was in the ability to convey complex temporal relations between events (the temporal envelope distinctions). First-cohort signers, who were at chance in the referential communication task, primarily rely on lexical items such as *STOP*, *WAIT*, and *NEXT*.

The second and third cohorts both performed above chance in the referential communication task, but differed in their distribution of the devices used. While the frequency of the use of lexical items increased from the first to the second cohort, it dropped back down for the third cohort. In contrast, there was a gradual increase in the dual use of hands across the three cohorts, suggesting that NSL may be converging on this particular device for indicating temporal overlap between two events. The use of simultaneous constructions to convey temporal information has been observed in a number of other sign languages, including ASL, British Sign Language, Danish Sign Language, Irish Sign Language, and Quebec Sign Language (Emmorey, 2002; Engberg-Pedersen, 1993, 1994; Leeson & Saeed, 2002; Liddell, 2003; Miller, 1994; Morgan, 2002; Rathmann, 2005). Simultaneous constructions may prove to be a sign language universal, taking advantage of the capacity for simultaneity in the manual modality, in contrast to the strict linearization required by vocal production (e.g., Emmorey, 1995; Padden, 1988; Perniss, 2007). While there is little developmental data on native signing children's acquisition of simultaneous constructions, this particular device appears to require considerable linguistic skill, since the signer must represent two referents or two events, one with each hand, and encode their locative or temporal relation to each other.

The complexity of this device may explain why first-cohort signers have greater difficulty with the Envelope events than with the Order events. The use of simultaneous constructions to describe temporal information may present a challenge of articulation or cognitive load for signers, who must manage the multiple components of these constructions, producing signs for two different events, one on each hand, and controlling the onset and offset of the manual movements to encode the temporal relation. Note that our subset of signers in Experiment 2 did not have difficulty with comprehending or encoding these temporal relations, suggesting that the slower emergence of the dual use of the hands to convey temporal relations (relative to devices for ordering information) is due to the greater linguistic complexity of their expression.<sup>5</sup> Simultaneous constructions may require certain high-level linguistic skills, such as a contrastive use of space and a violation of symmetry across the two hands, and such devices may be slow to emerge in a new language and consequently be absent in the language of the first cohort.

On the other hand, given the complexity of the simultaneous constructions, it is remarkable that they emerged over these mere three cohorts of language users. These constructions link two separate events into a single higher-level unit, and thus are distinctly more complex than the simple listing of events (parataxis) that Deutscher (2005) suggests characterized discourse prior to the cultural creation of connectives and subordination a few thousand years ago. This suggests three possibilities. First, rich linguistic encoding of temporal relations may not be as slow to develop as Deutscher's analysis would suggest, in either spoken or signed languages. Instead, the lack of connectives or subordination in early texts could reflect limitations in the historical record, the development of discourse conventions within the written modality, or cross-linguistic differences in the kinds of temporal devices that are preferred. A second possibility is that while spoken languages may be slow to converge on strategies for tightly

<sup>5</sup> We do not know whether this dual use of the hands is available in the co-speech gesture of the surrounding hearing environment. However, the observed increase in the use of dual hands across cohorts (with a significant difference between first-cohort and third-cohort signers) suggests that even if there is a similar use of two hands to depict two events in surrounding co-speech gesture, the oldest signers are not immediately capitalizing on it. Since it is unlikely that such co-speech gesture is available only to, or leveraged only by younger signers, we suggest that this use of two hands as a linguistic device cannot be immediately or easily co-opted directly from co-speech gesture.

linking two clauses, sign languages may develop them more rapidly because of the affordances of the modality, including the possibility of the simultaneous use of two articulators. Finally, it may be that the development of these linking strategies is linked to some other feature of life in a complex society, that would allow such structures to emerge in Semitic languages only after the advent of literacy, while enabling them to appear rapidly among urban users of NSL, who are immersed in large social networks and a literate culture, with frequent instances of displaced communication.

#### 5.4. Ordinal numbers in NSL

Experiment 3 was designed to determine whether our finding of cohort differences in the use of ordinal numbers was due to the nature of our temporal task, to a difficulty in using number to order transient events (though not objects), or to a general difficulty in using numbers to express ordinal relations. We found that older signers are able to use devices other than number signs to convey ordinality in a different task, though they do so infrequently. Thus, the later emergence of numerals to mark the temporal order of events does not appear to be due to a lack of understanding of ordinal relations. We did not observe any systemic morphological distinctions between the number signs used for the cardinal trials and the number signs used for the ordinal trials, perhaps because the overall use of number signs was low across the cohorts on the ordinal trials, or perhaps because such a morphological distinction is not present in NSL. Nevertheless, our data suggest that the number signs on the ordinal trials had the semantic function of ordinals because these signs systematically provided veridical information about order, and false information about cardinality. While it is possible that these number signs refer to the cardinal value of the set up to the point of the third bird rather than the ordinal position, we believe this is unlikely for two reasons. First, on the cardinal trials, signers from all three cohorts consistently produced number signs that correctly conveyed the final value of the items in the set, suggesting that signers are accustomed to using cardinal numbers to enumerate the complete set. Second, in the ordinal trials, the target object was distinguished in some way (e.g., the third bird was blue, see Fig. 10). Signers often produced modifiers (e.g., color adjectives) when providing information about the ordinal position of the target. As such, it seems unlikely that the number signs produced on the ordinal trials refers to a subset rather than the ordinal position given that only one object was distinguished in the relevant way (the third bird is the only blue bird). Third, signers' use of the other ordinal devices, such as the point-to-fingers, often contained cardinal and ordinal information, suggesting that they distinguish the two values. For instance, signers would hold up the number of fingers corresponding to the value of the set (four fingers) and then point to the third finger to indicate the ordinal position of a member of the set.

In the three age cohorts of signers studied here, we did not observe specifically ordinal linguistic devices, suggesting that the language is still converging on a systematic way for expressing ordinal relations. This slower emergence of ordinal words in NSL, relative to cardinal words, is in line with research showing that ordinal words are overall less frequent than cardinal words in spoken languages (Colomé & Noël, 2012; Miller et al., 2000). In some spoken languages, the same number words can be used for both functions, with no lexical or morphological distinction between them.

Additionally, the finding that ordinal numbers are slow to emerge in NSL is intriguing in light of developmental work indicating a later understanding of ordinality relative to cardinality in children (Colomé & Noël, 2012). Relative to the study of cardinals,

limited work has been done on the acquisition of ordinal numbers (Colomé & Noël, 2012; Fischer & Beckey, 1990; Meyer, Barbiers, & Weerman, 2015; Miller et al., 2000; Trabandt, Thiel, Sanfelici, & Schulz, 2015). Some work suggests that children acquire small ordinal numbers before large ordinal numbers (Colomé & Noël, 2012; Trabandt et al., 2015), but it is not yet known whether ordinal numbers are acquired in a stepwise fashion, similar to cardinal numbers. There is some specific evidence that the pattern of ordinal number acquisition may be affected by language-specific factors such as whether or not the language uses regular or irregular ordinal morphology (Meyer et al., 2015).

Given that ordinals arise later in the history of spoken languages (and are often derived from cardinals), it is not surprising that we did not observe a systemic morphological distinction in the form of number signs used in cardinal and ordinal contexts in our experiment. Further work is needed to better understand whether this later development in the history of a language reflects a conceptual hurdle or the need to develop linguistic machinery for deriving ordinals from cardinals. We favor a linguistic account for this pattern: the fact that we saw a systemic semantic distinction between the numbers provided on the ordinal and cardinal trials suggests that signers can both quantify sets and determine the ordinal position of a member of a set. Taken together, these findings suggest that while some numerical devices are available earlier in the emergence of a new language than others, concepts that can be and are marked linguistically in languages, like cardinal and ordinal numbers, appear to be available even to users of a language in which they are not yet marked. Linguistic marking does not seem to be required to be able to conceptually distinguish between cardinals and ordinals.

#### 5.5. Limitations and future directions

The study of emerging sign languages, such as NSL, offers a rare opportunity to better understand how historical and cognitive processes interact to give rise to human language. As is the case with all natural experiments, there are uncontrolled factors in the populations we study. One such factor is that our participants do not live in cultural isolation. Most live with extended families, including spouses and children. Many hold jobs, take public transportation, frequent various public spaces such as shops, and are immersed in the local community.

As such, NSL is not an isolated language and its users are not isolated from the surrounding Nicaraguan culture. It is quite possible that temporal language might not have developed as quickly if they were more isolated. However, recognizing a positive effect of cultural contact is different from identifying a source of temporal marking in NSL. There are three points worth considering in regard to this issue.

The first is that prior work has shown that immersion in culture is not sufficient to drive the development of a language within a single child, as in the case of homesigners. While immersion in a rich culture, exposure to temporal concepts through schooling, and access (albeit limited) to spoken Spanish may hasten the developing of the marking of temporality (compared complete cultural and linguistic isolation), such exposure alone cannot account for the pattern of emergence of temporal language we observe in NSL. Access to a spoken or written language that marks tense or aspect is insufficient on its own to drive the creation of new resources in a language to mark temporality; signers must also be able to interpret temporal markers in others' signing and converge on selected forms as a group.

Second, while many deaf Nicaraguans likely have had enough exposure to written Spanish to have noticed the marking of temporal information, this access is available to members of all three cohorts, and thus does not easily explain the pattern of



emergence and convergence on the linguistic markers for those concepts over the second and third cohorts, documented here.<sup>6</sup> Beyond a very general sense of temporal marking, knowledge of Spanish grammar does not transfer to the devices we have documented in NSL. Indeed, our data show that NSL did not even adopt the tense system of Spanish, but developed a quite different system of aspectual marking. It is similar to other, more mature sign languages in that it uses the three-dimensional signing space, but is not adopted wholesale from an existing sign language, as evidenced by differences between the systems, including some (apparently) intermediate stages in NSL.

However, exposure to written Spanish could influence the development of NSL in a more subtle way. For instance, being surrounded by a mature language may hasten the emergence of systems for marking information, such as temporality, in a new language. In addition, the development of a rich system of temporal marking may depend on other developments in the language, such as a rich set of verbs and classifier constructions. Once those components are in place, the language may be better able to build a system of temporal marking. Language contact may have an effect at this early point, as the language is laying its foundations, even if it cannot explain the pattern of change that occurs across the cohorts (who have similar levels of exposure to Spanish).

Thus, while it is possible that signers who were not immersed in a rich culture would have taken longer to mark temporal information, these concerns cannot explain the specific pattern of emergence we capture here. The development of temporal marking in NSL reveals the development of new ways to mark temporal information, not an increasing infiltration of the concept of temporal contrast into the community. Nonetheless, future work should investigate the influence of other relevant factors on the emergence of a language, including the effects of contact with other languages, education, literacy, technological advances, and the size of the community of users.

### 5.6. Conclusion

In sum, within our exploration of the emergence of temporal language, we found different patterns of development depending on the type of temporal information being expressed. The speed at which a language converges on preferred devices for conveying information may depend on the abstractness of the representations under consideration. While the capacity for representing temporal concepts appears to be present in the human mind, the linguistic devices to convey temporality do not emerge immediately, nor do they take hundreds of generations to construct. Instead, language creation and convergence may span just two successive age cohorts of child learners, as seen in the appropriation of linguistic forms from other domains, such as the use of ordinal numbers to mark the temporal sequence of a series of events, or even three successive age cohorts of learners, as with the expression of complex temporal relations between events.

How or why might linguistic structure, here a system for temporal marking, take a few generations to emerge? We have considered four possibilities. The first is that the emergence of a particular structure may be delayed by the need for convergence in the linguistic community. While the capacity to represent and

communicate different concepts may be present even in individual signers, the community must always converge on selected forms, leading to a delay in the production of systematic and reliable forms across signers. Depending on the content of the underlying representations, convergence may be slower or faster, as observed in the differences in the emergence of devices for conveying information about temporal order information compared to information about temporal relations between events. Factors that might lead to easier convergence include high frequency of use, the number of alternative encodings present in the earliest phases of language creation, and the degree to which the meaning or function of a form can be readily inferred from context by those who encounter it for the first time.

Another possibility is that the critical or sensitive period of language learning has a bottleneck effect on language emergence. Once a child, or a group of children, mature and become adults, they may no longer be able to effect change on the language (or acquire later changes in the language). A subsequent generation of children would therefore be necessary drive further development of the language. Language creation may be a product of multiple sensitive periods of learning, requiring at least several generations of children.

A third possibility is that complex temporal devices may be able to emerge only after other features of the language have stabilized. The temporal devices we studied are used to relate two or more events to one another. Doing this presumably requires that the signers have efficient and stable ways of representing events and their components (verbs and their arguments). For example, while signers from all cohorts had signs for the actions represented in the events, instances of dual use of hands employed a classifier handshape to represent the agent of the action and a movement to represent the action. That is, this device contains multiple components. The dual use of hands may only be possible once certain other features of the language, such as classifier handshapes, have stabilized and are accessible and componential to some degree.

A fourth possibility may be that temporal devices emerge over a couple of generations because their refinement depends on properties of the language acquisition processes. One constraint on a natural language is that it must be a system that can be transmitted and learned by a young child. As children acquire a language, they change the language (Senghas & Coppola, 2001). Through use, forms may emerge in the first or second cohort of signers that simply cannot be acquired by young children. Other forms may emerge only later because they result from child minds refining, mislearning, or reorganizing the input they are given (e.g., Hudson Kam & Newport, 2009; Singleton & Newport, 2004). If reiterative rounds of restructuring are required for a specific form, the process might take several generations.

For example, one might imagine that children may have a bias towards linguistic strategies in which the properties of an event are directly reflected in the form of the utterance. In spoken languages, claims like this have been argued to explain the subject-first preference in word order (e.g., Bever, 1970; Dowty, 1991; MacWhinney, 1977; Osgood, 1980). Perhaps the dual use of hands strategy of using one hand per event, and directly encoding the temporal relation between them, reflects children's bias for such analog mapping. Such an account would be predicted by those who propose that iconicity is central in children's acquisition of sign language (e.g., Thompson, Vinson, Woll, & Vigliocco, 2012). However, while iconicity is advantageous for adults and older children, very young children appear to be unable to easily leverage it in lexical acquisition (e.g., Magid & Pyers, submitted for publication), and there is no strong reason to believe that children would be more inclined to take advantage of iconicity at higher levels of linguistic structure. Indeed, the earliest temporal devices

<sup>6</sup> Members of the second and third cohorts do appear to be achieving a higher level of mastery of Spanish relative to first-cohort signers, particularly in written form. However, this mastery appears to be a consequence, rather than a cause, of having a richer, more developed sign language for daily interactions, from a young age. Research on deaf children's literacy has found that earlier exposure to a mature, natural sign language leads to better mastery of written language (see Mayberry, 2010 for a review), so it is not surprising that the later age cohorts of NSL are better equipped to learn to read Spanish.

to emerge in NSL are not ones that exploit similarities between the linguistic form and the real world that it describes. While one might predict that signers would capitalize on iconicity wherever possible in the creation of a new language, particularly in the manual modality (e.g., Barsalou, 1999; McNeill, 1992; Taub, 2001; Werner & Kaplan, 1963/1984), this strategy does not appear to be automatically favored. Rather than mapping language form directly to the structure of the events in the world being represented, such as describing a series of events in the order that they occur, first cohort signers of NSL instead tend to make use of lexical items to convey temporal information.

One might also expect that, once a device has been developed for a function, it would be readily taken up by subsequent generations of learners. However, the second cohort signers, as children, did not consistently match the input provided by the previous cohort. As the language is passed down from one generation of learners to the next, it is altered, rather than being faithfully reproduced. Thus, while the seeds of later-emerging structures are present in the signing of the first cohort, the language was reorganized in the transmission to a new cohort of learners, and infrequent devices were used with increasing frequency and consistency. Language, then, is a product of individual minds interacting within a community of multiple successive age cohorts of learners. As language is passed down, it is continuously taken up and changed, and each generation leaves its mark.

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## Appendix A

See Tables 8 and 9.

**Table 8**  
Stimulus characteristics of List 1.

Item #	Base event	Target	Variant
1	Order	Base	Medium Change
2	Envelope	Sequential	Staggered
3	Envelope	Nested	Simultaneous
4	Order	Easy Change	Base
5	Envelope	Simultaneous	Sequential
6	Envelope	Staggered	Delayed
7	Order	Hard Change	Base
8	Envelope	Delayed	Nested

**Table 9**  
Stimulus characteristics of List 2.

Item #	Base event	Target	Variant
1	Envelope	Delayed	Staggered
2	Order	Base	Easy Change
3	Envelope	Sequential	Simultaneous
4	Envelope	Simultaneous	Nested
5	Order	Hard Change	Base
6	Envelope	Staggered	Sequential
7	Order	Medium Change	Base
8	Envelope	Nested	Delayed

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