Convergence and Emergence: How Nicaraguan Signing Has Been Shaped by Transmission, Acquisition, and Interaction

Marie Coppola, Molly Flaherty, Deanna Gagne, Kurt Gagne, Annemarie Kocab, Amber Martin, Danilo Morales Blanco, Ivonne Morales RuÃz, Jennie Pyers, Ann Senghas

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MARIE COPPOLA, MOLLY FLAHERTY, DEANNA
GAGNE, KURT GAGNE, ANNEMARIE KOCAB,
AMBER MARTIN, DANILO MORALES BLANCO,
IVONNE MORALES RUÍZ, JENNIE PYERS, AND
ANN SENGHAS

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Abstract

Common features in sign languages that have no history of con-
tact present a puzzle. The current article brings together findings
from three studies of Lengua de Señas Nicaragüense (LSN) to iden-
tify processes that underpin the inception and changes in language
as it emerges. We use an *apparent time approach* to capture language

Marie Coppola is hearing and grew up with deaf parents in the United States; she
is professor of psychological sciences and linguistics at the University of Connecticut,
where she directs the Language Creation Laboratory. She is also founder of the non-
profit organization Signs and Smiles that advocates for deaf children's early access to
language and education internationally. Her research with deaf people in Nicaragua
began in 1994, and her research interests include homesign, numerical cognition,
and social cognition. Molly Flaherty is hearing and from the United States; she is
assistant professor of psychology at Davidson College where her research focuses on
the ways in which people shape language as they learn it. Her work with signers in
Nicaragua began in 2004. Deanna Gagne is hearing and grew up in a deaf family in
the United States. She is an associate professor of linguistics at Gallaudet University,
where her research focuses on how children learn language and contribute to the
development and transformation of language over time. Her work with Nicaraguan

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change in three domains: pointing and deixis, nonmanual markers with Wh-questions, and spatial differentiation for locatives and arguments. By comparing the language of Nicaraguan homesigners, three successive cohorts of LSN signers, and the signing of hearing children of deaf LSN signers (Codas), we propose that language change is characterized by two complementary processes, in balance: emergence and convergence. Emergence is the constructive process by which forms arise, such as new lexical items, new patterns of word order, and new mappings between forms and functions, such as a pointing sign taking on a pronominal function (study 1).

signing communities began in 2011. Kurt Gagne is a deaf researcher from the United States who earned a self-directed B. A. degree in language development and use from Gallaudet University. His work centers on sign languages and deaf communities, with a focus on homesign systems, late sign language exposure, and language development in children. He has worked with teams in Nicaragua since 2015. Annemarie Kocab is deaf and from the United States; she is assistant professor of cognitive sciences at Johns Hopkins University. Her work with deaf people in Nicaragua began in 2008. Amber Martin is deaf and from the United States; she is a doctoral lecturer in developmental psychology at Hunter College, with research interests in language and spatial cognition. Her research in Nicaragua began in 2009. Danilo Morales Blanco is deaf and has been using Lengua de Señas Nicaragüense since early childhood, when he began attending school in Managua, Nicaragua. He has worked with international researchers to document LSN from an early age, and has served as project director for the Deaf Research Team, a group of deaf Nicaraguans who collaborate with researchers from the United States on studies of LSN, since 2019. Ivonne Morales Ruíz is deaf and and has been using Lengua de Señas Nicaragüense since early childhood, when she began attending school in Managua, Nicaragua. She is a teacher at the Melania Morales Center for Special Education in Managua. She has worked with international researchers to document LSN from an early age, and has served as the team coordinator of the Deaf Research Team since 2019. Ivonne has also collaborated with the nonprofit organization Signs and Smiles, serving as a sign model for the smartphone application Señas y Sonrisas that helps parents and friends of deaf people learn basic LSN signs. Jennie Pyers is hearing and grew up with deaf parents in the United States; she is a professor of psychology at Wellesley College, with research interests in the ways that language and cognition interact throughout the lifespan. Her research in Nicaragua began in 2000 with her dissertation work on the relationship between theory of mind and language emergence in different communities of LSN signers. Ann Senghas is a hearing researcher from the United States. She first began her studies of signing in Nicaragua in 1989, as an assistant to Judy Kegl. She has been working with deaf Nicaraguans and documenting their language ever since; it was the subject of her doctoral dissertation in 1995. She is presently a professor of psychology and director of the Program in Cognitive Science at Barnard College of Columbia University, where she directs the Language Acquisition and Development Research Laboratory (LADR Lab).

We argue that vertical transmission from a more experienced user to a less experienced learner drives emergence, often via linguistic reanalysis in which the learner assigns a different function to a form than the one used in the grammar of the experienced user. Complementing the process of emergence, convergence is the reductive process by which competing forms and structures are condensed to a smaller set to achieve parity across a group of language users, a process exemplified by the selection of the brow furrow and head tilt to accompany Wh-questions (study 2). We argue that horizontal peer interactions are key to convergence processes; the language of learners who do not experience such peer interactions, such as homesigners and Codas, shows less convergence (study 3). Taken together, these studies illustrate how the developmental characteristics of the learner intersect with the characteristics of their language (internal ecology), environments, and interactions (external ecology) to drive the processes of language change. We conclude that both vertical transmission and horizontal peer interactions are key to the emergence of new languages, enabling the mechanisms responsible for the typological similarities observed across unrelated languages.

WHEN WE CONSIDER the varieties of sign languages in the world, we find striking commonalities at every level, from phonological forms, to the orders of elements within phrases and sentences, to systems of pronominal reference and verb agreement. Languages can share structural characteristics, such as markers for negation (Quer, 2012, Zeshan, 2006) or how questions are formed (Zeshan, 2004). Sometimes traits shared between languages point to a common origin or a history of cultural contact. For example, Abner and colleagues (2024) uncovered phonological similarities across 19 modern-day sign languages, providing a historical reconstruction of two families. Other research has identified common characteristics in languages with no history of contact (Zeshan & Palfreyman, 2017).

Crosslinguistic comparisons can reveal potential universal tendencies, such as certain traits that predictably pattern together within a language. For example, a sensitivity to the presence of an instrument in an event predicts a language's preference for object or handling handshapes in its lexicon (Brentari et al., 2016). There are even some language characteristics that appear in nearly all sign languages, such as mapping the extended index finger to the linguistic function of a

person reference (Lutalo-Kiingi, 2014; McBurney, 2002) and mapping signing space to grammatical arguments (Rathmann & Mathur, 2008; Sandler & Lillo-Martin, 2006).

These shared characteristics across languages present a puzzle. How do particular forms come to be applied to similar functions across unrelated languages? One possibility is that these mappings are so universally robust that they are necessarily present from the outset. Under this view, such features would be shared in the origins of all sign languages; that is, the languages all have a common seed. Accordingly, the shared characteristics are the residue of their common origins. Another possibility is that shared characteristics are the natural product of the way languages develop and change over time. Under this view, the languages may have begun as a more highly diverse set, each seed quite different from every other, and then due to common tendencies in how they are learned and used, they develop and change in ways that bring them more into alignment. Accordingly, the differences between languages are due to their separate origins, and the shared characteristics reflect the shared nature of change over time.

To address this challenge, we seek to capture innovation and conventionalization at the very earliest moments of language creation and change. Rather than looking broadly across unrelated or distantly related languages, we take a microtypological approach, comparing different subpopulations of learners in the context of an emerging sign language in Nicaragua, some of whom are exposed to each other's language use. We compare the signing of different generational cohorts within the Nicaraguan sign language community, and homesigners outside that community, and we compare idiolects within a household, between parents and their adult children. With these comparisons, our goal is not to assess whether a person's language includes or lacks some feature; rather, it is to measure the nature of change as language passes from one state to another. Does the change represent an increase or decrease in diversity of language varieties over time and generations? How is the nature of change affected by the context in which each new linguistic variety emerges? The studies reviewed in this article point to processes of language change that drive languages toward shared characteristics.

The Deaf Community and Signing in Nicaragua

The opportunity to make these comparisons is provided by the particular history of sign language use in Nicaragua (Kegl & Iwata, 1989; Senghas, 1995; Polich, 2005; Senghas et al., 2005). Before the 1970s, a few schools and clinics served some deaf children and adolescents, but without a continuous influx of new students, any signing that may have developed then was not passed on (Polich, 2005). This situation changed in the early 1970s, when a center for special education with dedicated classrooms for deaf students was established in Managua, the nation's capital, followed by the opening of a vocational school for adolescents with disabilities a decade later. While neither program offered instruction in a sign language, they did provide an opportunity for deaf children and adolescents to come together and socialize, and together the students created a shared sign language. The programs also enabled their language to be passed to new children entering school each year since then. What began as a community of 25 youths has now grown to over 1,600 deaf signers of Lengua de Señas Nicaragüense (LSN), who range in age from 4 to 65 years old today. Though our focus here is on characterizing the changes in this community's language, note that the Nicaraguan deaf community does not include the entirety of the country's deaf population. Approximately 90% of deaf people in Nicaragua are not part of the deaf community and do not have access to language or education (Coppola, 2020b); this prevalence is comparable to the 70% figure for deaf people worldwide who do not have access to a wider deaf community (World Federation of the Deaf [WFD], 2016), which the WFD notes is likely an underestimate.

One way to capture language change is to use an *apparent time* approach, taking older and younger signers today as a proxy for language states at the respective times that they learned it (Bailey et al., 1991). Of course, this proxy is not an exact replica, as people's own language changes over their lifespan. Even so, any differences that persist today between age cohorts can reliably be taken as changes to language over time. Accordingly, for research purposes, we often group the continuum of Nicaraguan signers into age cohorts by decade, with the *first cohort* being those who entered in the first decade

(1974–1983), the *second cohort* those who entered in the second decade (1984–1993), the *third cohort* those who entered in the third decade (1994–2003), and so on. We can then determine changes in the language as it was passed down by comparing these cohorts, each situated in a different social context.

A second comparison, between modern-day homesigners and LSN, allows us to measure how language might change when signers are first brought together into a language community. The original group of deaf students that arrived at the school in the 1970s likely had developed individual *homesign* systems to communicate with their families and friends. The language of modern-day homesigners serves as a proxy for the varieties of signing that initially seeded the language of the first cohort, with the caveat that modern-day adult homesigners have been using their signs their entire lives, unlike the children who arrived in school in the 1970s. Even so, differences between homesigns and first-cohort LSN signs can reveal some of the kinds of changes that take place as communication is taken up in a new, broader social environment. The homesign data reported in this article come from homesigners who do not have other deaf people in their families, nor do they have regular contact with other deaf people. However, the communicative networks and language ecologies of other homesigners in Nicaragua and in other parts of the world do include deaf signers with varying levels of interaction with their local deaf communities.[1]

A third type of comparison within the community compares changes within different language environments. We first measure differences between the signing of the first cohort and that of their adolescent and adult children (Codas, for Children of Deaf Adults), who are hearing bilingual users of LSN and spoken Spanish, who rarely interact with peers using LSN. We then compare the LSN of the Codas to that of second-cohort LSN signers, who use their language extensively with peers. Coda signing and second-cohort signing were both seeded by first-cohort signing, but were formed in different social contexts; thus, different outcomes between these two groups can reveal how the nature of language change is shaped by social context.

By comparing these different present-day varieties of Nicaraguan signing, we aim to capture the way that language naturally changes,

which will better inform our discussion of the potential mechanisms behind such changes. These comparisons should not be interpreted as indicating that some varieties constitute language and others non-language. Such a delineation cannot be empirically determined. All of the varieties we document here are examples of languaging and engage the creative language processes we seek to identify and understand (à la Henner & Robinson, 2023). Language will manifest in each individual in line with their life experience.

Similarly, we do not envision the language of various subcommunities of Nicaraguan signers as steps along a two-dimensional timeline of increasing complexity. As language is taken up by different community members, some changes include the creation of new structure, and some represent consolidation or loss. Moreover, the language used by the Nicaraguan groups in our study don't fall along some imagined continuum of language evolution with homesign at one end, small community sign languages somewhere in the middle, and older or larger community languages at the other end. Such hierarchical characterizations are overly simplistic and risk concealing the richness of language in all of its forms (Hou & de Vos, 2022, Moriarty & Hou, 2023). Rather, what we have observed, and what our studies show, is that the qualitative and quantitative differences among the groups can speak to the mechanisms that underpin language emergence and change. Each form of language emerges within an individual as a consequence of their unique combination of circumstances, including aspects of their language community and the forms of language to which they have been exposed (Senghas, 2005; LeGuen et al., 2020; Brentari et al., 2024). Understanding and characterizing these circumstances is central to our research question.

In our comparisons among groups of signers, we have selected a small number of specific domains of grammar to analyze. Our selections have been informed by research on other sign languages of the world, as well as by our own observations as we work and socialize within the Nicaraguan signing communities. In making these selections, we have prioritized domains where we expected to find measurable change. Of course, there are also many similarities in the language used by the different groups that we do not describe here.

Languages emerge and change as a function of an interactive relationship between the human learner and their environment. Mufwene (2002) describes languages as "complex adaptive systems" that emerge as idiolects in every learner, drawing from the rich and variable language to which they have been exposed across the individual's communicative experiences. We integrate this view with a developmental approach to analyzing change. What emerges in each individual will depend on the content available from the environment and the nature of the human learner, including the learner's stage of development (Goldin-Meadow, 2015). The environment and the learner are not separate, unique sources of structure (Gottlieb, 2007). It is the interaction between the environment and the learner that is the adaptive process that yields each individual's language content.

Language change includes the appearance of linguistic forms, the application of those forms to new functions and patterns of use, and the disappearance of forms or functions. The emergence of a sign language shared across a new, growing community provides a rich opportunity to observe such changes, as the communication situation is dynamic and rapidly changing. At the inception of any system of communication, the system will be characterized by high variability. For any new linguistic element, precursors or incipient forms may be identifiable in the language of current members of the community. Using an apparent time approach, the spread or loss of an element, such as grammatical uses of pointing or facial expressions, can be tracked based on their distribution across older and younger members of the community. This approach reveals that changes that typically unfold over centuries in an older language can sweep across a young language community within a single decade.

Emergence and Convergence

We document a tension between two kinds of change. *Emergence* is the appearance of new language structure; it is innovative. It entails the creation of connections, such as the mapping between a syntactic construction and a semantic role, between a word and its meaning, or in the patterning across different grammatical domains of the language. Emergence occurs within an individual's idiolect; that is, a structure could emerge within the language of some community members and

not others. *Convergence* is a shift to greater parity across members of a language community. It can entail the loss of elements in the language of some individuals, perhaps as they take up competing forms that are used by others. Convergence can also refer to the parallel adoption of new structures through contact, shared learning tendencies, shared adaptive pressures, or chance, bringing the languages into alignment in some domain. One can also observe convergence across multiple subsystems within any larger system, including across domains within the grammar of a single idiolect. For example, an individual could converge on a coherent system of word order used across different types of phrases. Initially, the emergence of a new form in someone's language represents divergence from, rather than convergence with, their language model. A new form appearing and spreading throughout a community would represent a case of emergence followed by convergence.

Studies

In the present article, we revisit three studies by members of our research team comparing the language of different subcommunities of Nicaraguan signers. These studies documented changes in Nicaraguan signing in different language domains and across different profiles of language users. We bring them together here to examine how the ecosystem of the language, that is, factors including community structure and the ages of learners, affects the kinds of changes we observe. What conditions lead to the emergence of new structures, and what lead to convergence across signers' language systems? The first study considers uses of the pointing sign in the language of homesigners and three age cohorts of LSN, capturing the emergence of nominal uses of pointing as LSN is acquired by new signers. The second study describes how successive cohorts of LSN converged on a nonmanual marker for WH-questions, drawing candidates from the facial gestures in their environment. The third study examines the grammatical use of space in LSN, and how two groups that learned from first-cohort signers—deaf members of the second cohort and hearing children of first-cohort signers—ultimately acquired differing spatial conventions, exhibiting patterns that also diverged from their shared first-cohort model.

These three studies are a selection from a body of research conducted among deaf people in Nicaragua over the course of 35 years. In addition to enabling this microtypological review, they represent the logic of our approach to exploring a wide range of experiences and interactions of signers in various circumstances, and the resulting variety of linguistic structures. An important aspect of our approach is in the diversity of our research team: We include deaf, Coda, and hearing researchers from the United States and Nicaragua, and those of us in academia work in different academic departments and types of institutions. We interact directly with all of the participants, without interpreters or other intermediaries. In earlier years, researchers from the United States engaged participants while living in the community for months at a time. Today, the majority of data are collected by members of the Nicaraguan Deaf community who have worked with international team members for decades (Gagne et al., 2022).

Study 1: Pointing and Deixis

The differences in uses of pointing in homesigners and the first three cohorts of LSN signers exemplify the rapid changes characteristic of language emergence and illustrate how language users and learners seek to accomplish certain functions of language, such as identifying the location of an event or referring back to a character who has already been mentioned. The use of an indexical point to a locus in the signing space for these two functions has been documented in many sign languages around the world (Sandler & Lillo-Martin, 2006). Coppola and Senghas (2010) and Senghas and Coppola (2011) sought to identify when and under what circumstances such linguistic uses of pointing emerged. They asked participants to watch brief cartoons and narrate the events to a peer, and then coded the narrations for locative points (which refer to locations) and nominal points (which refer to characters).

Two main findings emerged regarding the forms of each type of point and their position within a sentence. First, the articulated forms of the two types of points differed: Locative points tended to be bigger, articulated beyond the neutral area bounded by the waist, chin, and shoulders, with the signer's eye gaze following the direction of the point (Figure 1a). In contrast, nominal points were smaller, staying

within the neutral area in front of the torso, with the signer's eye gaze also remaining neutral, not following the direction of the point (Figure 1b).[2] The two types of points' position within the sentence also differed: Locative points often appeared in adverbial position, after the verb, whereas nominal points appeared where a noun would go, that is, before the verb. Figure 2 presents the relative frequency of each type of point in the productions of the four groups investigated. While locative points were high in frequency and relatively stable across the four groups, nominal points were infrequent in the signing of homesigners and cohort 1 signers, and increased across the signing of cohort 2 and cohort 3. We interpret this pattern as evidence for the emergence over LSN's first three decades of a new form-function mapping: A smaller, constrained form of the indexical point is now applied to the pronominal function of referring back to a previously

(a)   (b)
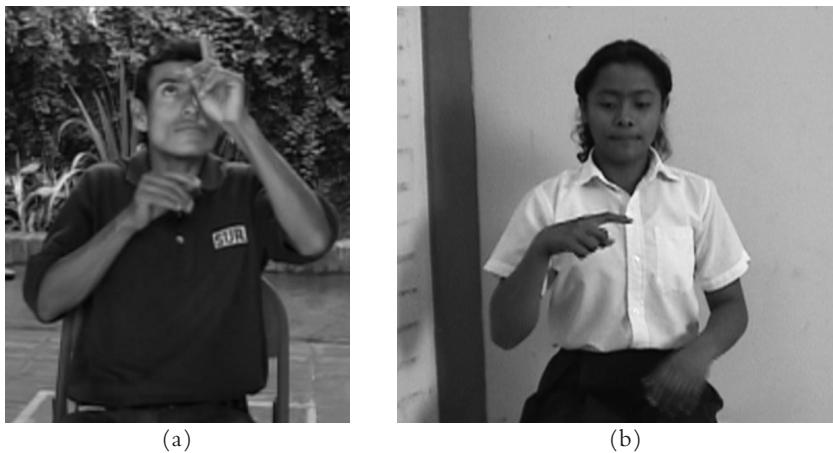
FIGURE 1. An example of a locative point produced by a homesigner in which he describes the location of a character by pointing upwards (Figure 1a); an example of a nominal point produced by a cohort 3 signer in which she produces a point to her left to refer to a character (Figure 1b). Note that in the locative example (Figure 1a), the signer's eye gaze follows the direction of the point, while in the nominal example (Figure 1b), the signer's eye gaze looks forward toward a neutral space in front of the signer. Also, the hand in the locative example 1a is above and outside of the neutral area in front of the signer, while in the nominal example 1b, the hand is within the neutral area bounded by the waist, chin, and shoulders.
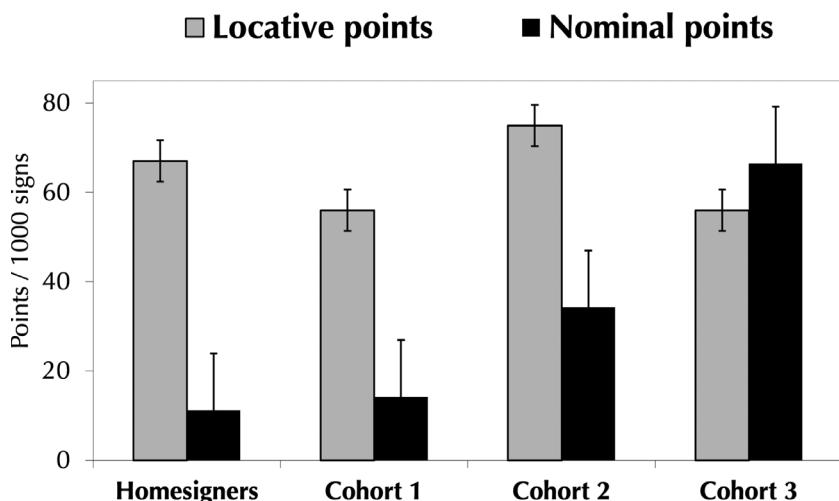
FIGURE 2. Relative frequency of locative (gray bars) and nominal (black bars) produced by homesigners, cohort 1, cohort 2, and cohort 3 signers. Note that while the frequency of locative points is relatively high and stable, the frequency of nominal points increases across types of signers. We interpret this pattern as evidence for the emergence, over LSN's first three decades, of a new form-function mapping, namely, pronominals, that allows signers to refer back to characters that have been mentioned previously. (Figure reprinted from Senghas & Coppola [2011] with permission from Oxford University Press.)

mentioned character. We have captured a time-lapse sequence of the emergence of a new grammatical element, a pronoun, in LSN.

By comparing narrative productions across different types of signers, we have retraced the initial stages of points used for this pronominal function. Note that signers did not need to create a wholly new form to fulfill this function. Already, some homesigners produce points for both locative and nominal functions, though the nominal uses are produced infrequently and not by all individuals. In order to repurpose a locative point for a pronominal function, signers had to bleach the form of its other meanings (e.g., the "where" or locative aspect) before creating a mapping to its new function, in this case, an anaphoric function. We expand on this cycle of the building up and erosion of meaning, and parallels documented in historical linguistics, in the discussion.

The robust appearance of the pronominal element among early signers of LSN suggests that learners come to the task of language creation with certain expectations (Slobin, 1996), including that humans are inclined to construe events in certain ways in order to express them; that the construals often include an agent or actor; that a mapping exists between classes of forms and classes of functions; and that agents and actors are expressed using nominals. In the changing use of points in LSN, the emergence of a form–function mapping constitutes a grammatical element getting assigned to a different component of an event, in this case, talking about the *who* instead of the *where* of the event. Thus, what has emerged is not new words, but new grammar—the mapping between the construal of the event (the "meaning") and the expression of that event (the "form") (Naigles et al., 1993). This mapping is the basis of argument structure, separating nominal and predicate, and linking the structure of the sentence to the construed structure of events in the world.

Study 2: Nonmanuals Used with Questions

In the second study, we turn to how nonmanual features become associated with different linguistic functions. Kocab, Senghas, and Pyers (2022) examined the facial expressions that hearing Nicaraguan nonsigners and LSN signers use when asking Wh-questions (e.g., what, where, when). To elicit these facial expressions in the context of questions, they asked pairs of participants to conduct interviews with each other, with the goal of getting certain information from their conversation partner. To avoid expressions of strong emotion or surprise, the interview subject matter concerned ordinary, everyday topics such as bus routes, wake-up times, and places in everyday life. In this way, the researchers were able to elicit natural questions (e.g., "Where did you go to school?") and observe the nonmanual facial expressions that accompanied them.

Four groups of participants were compared: hearing Spanish speakers, cohort 1 signers, cohort 2 signers, and cohort 3 signers. Across the four groups, six different nonmanual expressions were observed: the brow furrow, brow raise, nose wrinkle, chin lift, head tilt, and shoulder raise. Examples of these nonmanual expressions are given in Figure 3, as well as information about their correspondence
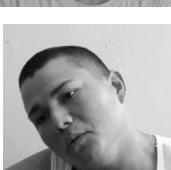
Nonmanual	Description	Example
Brow furrow	Corresponds to Ekman's facial action unit 4 (AU4). Comprises a pulling together of the eyebrows that often is evidenced as vertical wrinkles between the eyebrows.	
Brow raise	Corresponds to a combination of Ekman's facial action units 1 and 2 (AU1+AU2) where both the inner and outer brow are raised, often resulting in lines on the forehead.	
Nose wrinkle	Corresponds with Ekman's facial action unit 9 (AU9) which involves a pulling up of the nose and a deepening of the creases on either side of the nostrils, often with a horizontal wrinkle across the bridge of the nose.	
Chin lift	Operationalized as a tilting of the head backwards to raise the chin. (This movement *does not* correspond with Ekman's facial action unit 17 "chin raiser.")	
Head tilt	Any tilt of the head to the left or right of a neutral head position, also referred to as a "head cant" (e.g., Goffman, 1979)	
Shoulder raise	Any movement of the shoulder upwards from a neutral position; often looks like a shoulder shrug.	

Figure 3. Descriptions and examples of each of the nonmanual expressions used when asking Wh-questions: brow furrow, brow raise, nose wrinkle, chin lift, head tilt, and shoulder raise. (Reprinted from Kocab et al., 2022, with permission from *Languages*.)

with prior work on these expressions (e.g., Ekman's facial action units (Ekman 1979) and Goffman, 1979).

Comparisons across the four groups reveal that over time, this original set of six facial expressions was narrowed down to the two that presently dominate, reflecting a process of convergence. Specifically, among cohort 1 signers, we observe six possible nonmanuals for marking Wh-questions; however, among cohort 3 signers, who entered the community two decades later, we observe that only two, head tilt and brow furrow, are now frequently produced alongside Wh-questions (Figure 4).

This pattern suggests that LSN began with high variability in the nonmanuals, with each equally favored among the first-cohort signers, and moved to less variability as subsequent cohorts of signers reduced their production of some nonmanuals in favor of others.
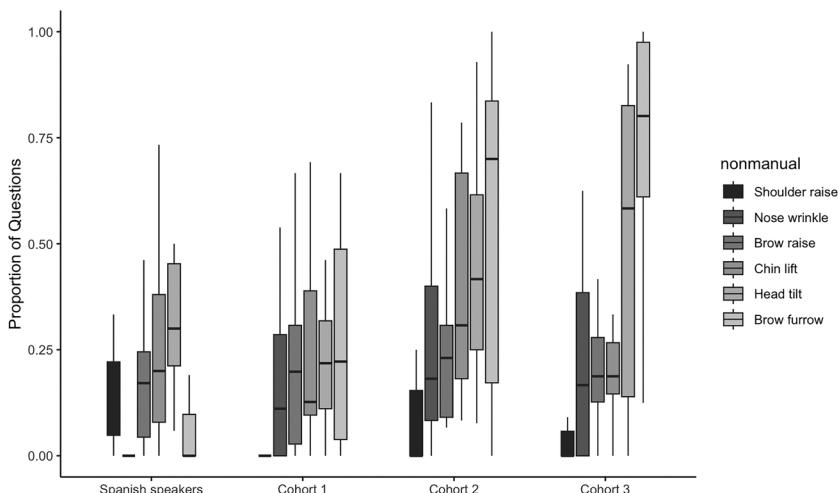

Figure 4. The proportion of questions with each type of nonmanual, across four groups. The black line indicates the median value for each nonmanual type. Whiskers indicate the maximum and minimum values, excluding extreme outliers. The nonmanuals are ordered according to their mean frequency over all groups combined, with the more frequent nonmanuals to the right in each grouping. The brow furrow, at the far right, had the greatest frequency overall, increasing across the three cohorts of LSN signers, though it was infrequent in the expressions of Spanish speakers. (Figure reprinted from Kocab et al., 2022, with permission from *Languages*.)

Over time, and as more learners joined the signing community, the meaning of forms evidently became more constrained and specific, where fewer nonmanuals are used for a specific function, here, asking Wh-questions. Such pruning appears to happen similarly across both related and unrelated sign languages, resulting in similar end-states (Zeshan, 2004). This convergence on a small number of forms to signal Wh-questions required agreement across some members of the language community regarding the mapping of Wh-question meanings to forms; furthermore, these mappings had to be noticed and taken up by new learners.

Thus, there are likely both statistical and semiotic contributions to this convergence: From a statistical standpoint, the frequency of a mapping is likely relevant: The more a nonmanual is produced alongside a syntactic structure, the more likely a strong association will emerge. Additionally, how well a linguistic form functions to signal its meaning will also enhance its learnability. Note that the brow furrow, one of the most common forms used by signers of cohorts 2 and 3, is rarely produced by hearing Spanish speakers in Wh-question contexts. Only with time and interactions within and among cohorts of LSN signers does it emerge as an effective nonmanual signal for Wh-questions, perhaps because of its visual salience or its ability to hold scope for longer stretches than some other contenders. Regardless, convergence is illustrated in the pruning down to a smaller set of candidates from a larger set.

Study 3: Spatial Differentiation for Locatives and Arguments

In the third study, we review evidence that signers' previous experience with the language, combined with the structure of their language community, affects the kind of structure that emerges. In the previous two studies, we documented changes over time and learners, based on differences between signers, starting with cohort 1, who provided language input to cohort 2, who, in turn, provided input to cohort 3. However, there are other patterns of transmission that can occur within a language community. Senghas, Senghas, and Pyers (2005) reviewed the history of the LSN language community and its social structure. Importantly, they distinguished interaction among peers of the same age in the school context, referred to as *horizontal*

interaction, from interaction between a more experienced, older user of the language and a less experienced, younger user of the language, referred to as *vertical* interaction. As the first students to arrive at the new school, cohort 1 signers lacked older sign language models, but they did interact with each other. Thus, they experienced horizontal interaction, but not vertical interaction. When the younger cohort 2 signers arrived, they engaged in vertical interaction with the older cohort 1 signers, as well as horizontal interaction with each other.

Senghas and Coppola (2001) reported on systematic changes in the grammar of LSN following its transmission from cohort 1 to cohort 2. These changes included changes in the use of signing space to indicate coreference. Signers were asked to watch a short video and retell its story to a peer in LSN. In their narratives, cohort 2 signers would produce signs at or toward the same locus in the signing space when referring to the same character or location in the story. That is, their signing included coreferent uses of space. Cohort 1 signers did not show this pattern; in their narratives, a shared locus of signs did not systematically correspond to coreference. Using an experimental methodology, rather than the narrative retelling method, Senghas et al. (1997) and Senghas (2003) replicated and extended these findings, affirming the systematic differences between cohorts 1 and 2 in terms of their production of spatial modulations,[3] as well as their interpretations of the use of space when mapping signs to argument structure roles. In accordance with previous work showing that young learners can systematize inconsistent linguistic input (e.g., Singleton & Newport, 2004), Senghas, Coppola, and colleagues (1997) attributed these changes to the vertical interaction experienced by cohort 2 signers as they learned the language from their cohort 1 models. However, cohort 2 also experienced horizontal interaction when communicating with their same-age peers. Did that horizontal interaction also play a role in these changes?

This final study disentangles the effects of vertical and horizontal interaction on the use of spatial devices for marking argument structure by comparing the productions and interpretations of spatial modulations by signers from cohorts 1 and 2, as well as adolescent and adult hearing children of cohort 1 signers (Codas). Codas experienced vertical interaction with their deaf signing parents, but did

not report any horizontal peer interactions using the sign language, even with their hearing siblings. Put another way, we are asking how convergence differs when transmission occurs only vertically (from the model to the child, with no peers), compared to when it occurs both vertically and horizontally.

The hybrid design of Gagne (2017) and Gagne et al. (2019) mirrored the structure of the experiments in Senghas et al. (1997) and Senghas (2003), adding a more natural narrative component. Signers described events like the one depicted in Figure 5 (a woman giving a cup to someone on her right), and their productions were coded as Rotated (the verb includes a movement to the signer's right); No Direction (the verb includes a movement toward neutral space; or Unrotated (the verb includes a movement toward the signer's left). These were the most commonly observed spatial strategies. A signer producing both Rotated and Unrotated forms across the task (i.e., an unconstrained use of space) would be considered not to be using space to mark arguments. A signer producing only one type of form, either Rotated or Unrotated (i.e., a constrained use of space) would be considered to be using space to mark arguments. Consider the event depicted in Figure 5 in which the woman gives a cup to the person to her right. If a signer were to describe that event by signing WOMAN in accordance with a Rotated layout (i.e., to the signer's right), followed by the sign GIVE-CUP in accordance with an Unrotated layout (i.e., to the signer's left), their interlocutor would not be able connect the two signs in an agreement-like way. Thus, the distinction is not only about surface consistency across productions, but also about whether spatial locations are used in a way that supports a stable and interpretable mapping between the form and meaning. Linguistic use is not simply the repetition of a strategy; it is the reliable use of reference in a way that can be understood by others. Consistent use, both within and across signers, reflects a shared, grammaticalized understanding of how space maps onto meaning.

In their descriptions of these events, cohort 1 signers produced both Rotated and Unrotated forms (both within and across signers), meaning they did not use signing space in this way to mark arguments. Cohort 2 signers consistently used a single layout; indeed, all of the cohort 2 signers consistently used the same Rotated layout, reflecting

a constrained use of space to mark arguments. (Note that these results replicate the findings from Senghas (2003) with an almost entirely new set of participants, with 20 more years of using the language and interacting with younger signers.) In contrast, the signing of Codas was more variable, with some using both Rotated and Unrotated forms, and some using only one or the other. When a Coda consistently used only one layout, it was most often Unrotated.

These results show that the structure of social interaction within a community influences the patterns of change in its language. The nature of the system that emerges depends on multiple aspects of the structure of the community, including its size (e.g., a family of four to six people for Codas vs. 600 members of the LSN-signing deaf community at the time that cohort 2 signers arrived), as well as the opportunity for communicative interaction among peers and across generations.

The variation in spatial strategy among Codas can be partly explained by differences in their language experience with LSN, particularly through their exposure to cohort 1 signers. First, the cohort 1 adults in their lives (their parents and their parents' friends) often produced spatial modulations in an unconstrained manner (both within and across individuals), providing highly variable input with respect to how space maps onto argument structure. Second, these cohort 1 adults may not have had a consistent interpretation of others' signing, with respect to how their spatial modulations map (or do not map) to meaning. This variability limits the reinforcement of certain patterns of mappings through the interpretation of others' utterances over repeated interactions. Finally, individual differences among the Codas themselves likely contribute to variation, including how they may regularize input or resolve ambiguity. Further study of the language used by Codas born to subsequent cohorts of signers, who would be providing a more constrained language model, could shed some light on the factors that underpin the observed variation.

In this third study, we can see how the presence of horizontal interaction affects the nature of change in language structure. We examined the use of a differentiation of the signing space to indicate argument structure. None of the first-cohort signers made use of spatial contrasts to indicate the participants in events, indicating that

Figure 5. Example of a stimulus event (top) and the coding categories of responses (bottom) from Gagne (2017). In the stimulus event, the woman gives a cup to a person to her right. In the participant's response, producing the verb with a movement to the right would be coded as Rotated; producing the verb in neutral space would be coded as No Direction, and producing the verb with a movement to the left would be coded as Unrotated.

they did not have this as a grammatical device. Instead they made use of another device, namely, word order, for this function (Senghas et al. 1997). Their language provided a model to both their own Coda children, who did not have access to horizontal interaction in LSN, and to second-cohort signers, who had a large peer community that provided extensive horizontal interaction. Despite the undifferentiated use of space by their parents, some of the Codas produced a systematic use of space that could be mapped to syntactic arguments in their signing. However, most of them, like their parents, did not use space contrastively, and there was no clear pattern across the individual Coda participants. In contrast, all of the second-cohort signers used space contrastively, and all of them used a consistent

pattern of mapping sign-space to real-world space, using a Rotated representation.

Discussion

The three studies described here, along with other previous research, provide a picture of highly dynamic, interacting language systems in Nicaragua. The documented changes include examples of both the emergence of language structure and convergence across systems. These processes of emergence and convergence are shaped by the social context of the language users.

Emergence is evidenced whenever linguistic content arises in the idiolect of a language user that was not systematically present in the language models to which that user was exposed; something new is added to the language. Examples include new lexical items, new patterns of word order, and new mappings between forms and functions. The first study documented the emergence of a new form-function mapping: A sign that had previously been used to indicate a location was repurposed to become a pronoun. This new use of pointing did not replace the locative function of points; it was added to the existing system. Signers with both functions in their language also created a differentiation in the forms of the pointing signs, in the accompanying eye gaze and the tenseness of the sign's movement. The emergence of the new element also entailed subtraction; the original association with an analog location in the world has been stripped from the sign. This bleaching of meaning made the sign available to be mapped to its new indexical meaning.

Vertical Interaction Enables Emergence

We propose that the emergence of new linguistic structure is most enabled by vertical interaction, in the transmission of language from an experienced model to a learner. When learners are building their idiolects, they may derive new connections from patterns in the language produced by their models, connections that are not, in fact, widely present in the grammars of the older individuals who generated that model language. The derivation of new connections among patterns entails reanalysis, repurposing, and restructuring on the part of learners. Of course, some language elements can emerge in an

individual's idiolect through horizontal contact among peers—people continue to add to their lexicon based on peer interactions throughout their lives (Pyers & Senghas, 2009). But we argue that the kind of changes that entail restructuring within a grammatical system, such as the connections between syntactic structure and semantic roles, appears to occur principally during vertical transmission from older, more experienced language users to new, younger language users. Evidence for this vertical effect lies in the unidirectionality of language change—although vertical interaction engages two parties in a linguistic exchange, it is only in the language of the younger party that restructuring takes place. In our data, the language of the first-cohort signers remains stable in certain domains, even after decades of interaction with second- and third-cohort signers who consistently use newer emergent constructions.

A system of language will be effective for communication only to the degree that it is shared. Convergence is evidenced when systems are brought into closer alignment, by using similar forms for similar functions, increasing similarity across the language produced by individuals. Interestingly, two systems might converge on similar structures in the absence of contact among language users. The similarity across systems in form-function mapping may arise because of shared learning tendencies of the language users or shared adaptive pressures of the language environment. Identifying commonalities among unrelated languages can help reveal such tendencies and pressures that drive convergence. When given highly consistent input, learners converge with their language models in a constant process of adapting their own language production to more closely match their input. Unlike emergence, convergence takes place "upward" in a vertical interaction during learning, when a learner changes to match more experienced language users. This learning process leads to stability in a language across generations. However, when language models are internally inconsistent or highly variable across individual idiolects, subsequent learners can converge on a stable system, although this convergence cannot robustly happen from vertical interaction alone, as evidenced by the way that younger cohorts of Nicaraguan signers use structures that diverge from their input language.

Horizontal Interaction Supports Convergence

With horizontal interaction, a learner's contact with peers who are also in the process of learning the language allows for individual language systems to adapt dynamically with each other. Learners can take up forms used by others and drop structures that are not shared by others, resulting in convergence across a group. In this way, horizontal interaction can have a subtractive or streamlining effect, as well as promote the wider adoption of newly emergent structures. The second study documented this process of convergence in the selection of nonmanual markers for Wh-questions. As each successive cohort learned LSN, the distribution of nonmanual markers changed, until two—the brow furrow and the head tilt—came to dominate in the language of the third cohort. Note that the device that is the most frequent among the third cohort, the brow furrow, was the least-frequent facial gesture for hearing Spanish speakers. This highlights two points: First, as the language evolves over transmission, it does not have a "memory" of its origins. Patterns in the seed that are not taken up by a generation do not survive to be transmitted to later generations (Kirby et al., 2008). Although LSN signers interact regularly with hearing Spanish speakers, LSN no longer draws grammatical elements directly from hearing gestures, even though those gestures likely provided original raw materials from which LSN was built (Coppola, 2020a). The language model for each cohort is the signing of the previous cohort, with further convergence taking place among peers of subsequent cohorts. What affects the persistence of any possible form is likely a combination of relative frequency (Kocab et al., 2019) and the suitability of that form given other potential advantages, such as the furrowed brow offering the possibility of being held continuously over several signs to mark the scope of Wh-questions (Kocab et al., 2022).

The presence of horizontal interaction is central to how language can change. In the relative absence of peer interaction in LSN, Codas ended up with a different use of signing space than second-cohort signers, even though both groups were exposed to similar first-cohort signing as their language model when they were children. This effect is shown in study 3, where we found that though none of the first-cohort signers consistently used spatial contrasts to mark who did

what to whom (using word order for this function instead), some of the younger signers who learned from them did use spatial contrasts consistently for this purpose. Younger, second-cohort LSN signers, with a large peer community allowing for horizontal interaction, all used space contrastively to indicate argument structure relations. The Coda children of first-cohort signers, whose signing models were their parents, however, mostly did not use space contrastively, highlighting the essential role of peer interaction in the convergence on this grammatical device both within and across individuals.

Emergence, Convergence, and Language Ecology

Processes of emergence and convergence combine to manifest the appearance, spread, and loss of elements in language. Their balance depends on the ecology in which the language emerges. For example, environments that provide a succession of generations with intergenerational contact will yield vertical transmission in which language elements can be selected and passed on. Highly variable language models will lead to rapid and significant change (Kocab et al., 2022), and peer communities will provide opportunities for dynamic convergence across the group (Gagne et al., 2019). Language change thus takes on a cyclical nature in which new forms appear, take on new functions, and are then replaced. For this reason, we resist characterizing these processes as leading to an overall increase or decrease in complexity. Complexity is not a meaningful concept at the level of a whole, changing language system. Just as one can build a highly complex house with simple bricks, a language with simplicity in one domain can be balanced with complexity elsewhere.

Additionally, global characterizations of complexity in sign languages and other marginalized languages (such as creole languages) can be dependent on inappropriate assessment metrics, including instruments developed in one context used to assess language data in another, as well as a bias in theoretical commitments, with complexity measures reflecting colonial language ideologies (see Bisnath et al., 2025). For these reasons, rather than assessing the complexity or stage of maturation of a language at any one moment, it is our goal to capture the specific nature of changes in language and discover the drivers of that change.

Homesign presents an interesting (and challenging) set of circumstances. The homesigners included in these studies do not exist in a community with other homesigners. Their closest communication partners, hearing friends and family members, do not acquire the systematic elements of the homesign system (Carrigan & Coppola, 2017). This means that the homesigners lack both vertical and horizontal linguistic interaction and must take on significant load in building their communication systems. Consequently, we observe a large degree of emergence in homesign, but little convergence. Even after decades of daily communication within the context of the family, homesigns in Nicaragua are characterized by multiple versions of lexical items referring to everyday objects—a homesigner might have a different sign for *dog* to use with each family member (Richie et al., 2014). While homesigners' hearing family members and communication partners do use homesign with the homesigner, they use only spoken Spanish with each other. Results from a computational model comparing the social networks of first-cohort LSN signers and homesigners suggest that the sparse interconnectedness of the homesign family networks underlies the relatively low degree of lexical conventionalization in homesign families. Another manifestation of the robust emergence and weaker convergence that results from the lack of vertical and horizontal interaction is that Nicaraguan homesigners have a larger handshape inventory that includes more complex handshapes than do LSN signers (Brentari et al., 2021).

Codas represent another interesting intersection of social circumstances and language use. The Nicaraguan Codas have the advantage of acquiring their parents' sign language from a young age, yet they have far fewer interlocutors than deaf LSN signers, using the language predominantly with their parents. Crucially, they never use the language with same-age peers (Gagne, 2017). Their primary language is spoken Spanish, which they use in all other social interactions. (In this way, they are similar to the family members of homesigners.) At the individual level, we do observe some changes when the language is passed from first-cohort parents to Codas, but the Codas never converge on a common system as a group, and most strikingly, do not match their parents in terms of the use of signing space for coreference. Thus, having a larger peer group seems essential to convergence.

The larger peer group may serve to increase the amount of nonshared knowledge that is conveyed through communication. Some evidence indicates that more shared knowledge reduces communicative pressures for linguistic specificity and conventionalization (e.g., Mudd et al., 2022; Meir et al., 2012). Within the small community of a family, communication partners can make reasonable guesses about a sign's potential meaning, given their knowledge of the greater context and shared personal situations. Making use of shared knowledge can make communication successful in the absence of conventionality, but it is effortful and depends on communicators' willingness to engage in the process of understanding (Green, 2022). While the engagement of multiple co-creators in communication is required for conventions to emerge, the resulting linguistic conventions ultimately can reduce the effort needed to achieve understanding in a new conversation. When signers share less knowledge, communicators are driven to increase the specificity and clarity in their language, which, in turn, may foster processes of both emergence and convergence.

When a new language emerges within a community, the age of learners is likely to be a highly significant aspect of the ecology of the language. Because language transmission most commonly occurs when learners are young children, the relevant natural learning tendencies of child learners are likely essential in the process of language emergence and change. The way that children acquire language will determine how forms are perceived and remembered (e.g., Hudson Kam & Newport, 2005), how events are construed and mapped to sentence meaning (Naigles et al., 1993), the potential distances between co-indexed elements, and so on, affecting every domain of language. When the environmental pressures posed by the context of language transmission lead to selective uptake from the input, and convergence across systems, the nature of child learning will influence what is taken up and what items converge.

The emergence of linguistic structure is not limited to new languages; it can occur at any time in the life of a language. Researchers have observed that forms can be repurposed for new functions even in much older sign languages. For example, in ASL, the reflexive pronoun SELF has been grammaticalized to be used as a copula (Sampson & Mayberry, 2022). This change, like the change in LSN

pointing, is consistent with an arc in the progression of historical change, whereby pointing gestures are grammaticalized to form locative signs, followed by pronouns, and then agreement markers and auxiliary verbs (Pfau & Steinbach, 2006). Such similarities between language emergence and historical change indicate that these language transitions may be driven by the same underlying processes. Any variability in the language model provides an opportunity for reanalysis over transmission, leading to the emergence of new constructions. In the case of a newly formed language community, the language pool is highly variable, so change is more rapid and extensive. An emergent language need not be a qualitatively different kind to a mature language; it simply must include more newly emergent structures and a high degree of variability across its communities of users.

In the same way that the external ecology of a language influences how that language is taken up by a learner, the internal ecology of a language influences how it can integrate a new linguistic element. The emergence of a new mapping between form and meaning may depend on or build upon systematicity in other domains. For example, the grammatical use of space, as in the use of pronominal points discussed in study 1, likely depends on the systematic, contrastive use of space described in study 3. In this way, change in one domain of a language can have cascading effects on other subsystems within the grammar. We see such an interdependence in the emergence of other spatial devices in LSN that resemble spatial devices across other sign languages (Kocab et al., 2015; Pyers et al., 2015).

Young Learners Drive Language Change

Let us return to the puzzle that we posed at the opening—why is it that unrelated languages share so many characteristics? How did sign languages around the world come to exhibit so many similar mappings between form and meaning? The answer lies in the mechanisms behind language change. Child learners play a critical role, bringing an approach to learning that results in a language that does not precisely replicate its model. Transmission allows the changes to accumulate over generations, shaping the language as certain features are selected and maintained. We know that language can't be too highly

determined by learners, like a set blueprint, or we wouldn't observe the diversity that we do. The nature of learning tendencies does not lay down content; it leads to similar kinds of changes to similar kinds of input. Recall how the changes we observed in pointing are similar to historical changes in other languages. There is apparently something about indexing that provides good grist, a few rounds down the line, for a pronominal function. On the other hand, if transmission provided pressures that predictably organized language based solely on its content, we would observe the same seed yielding similar outcomes in different types of communities. Recall that Codas and second-cohort signers received similar input, but ended up with different systems of LSN. Evidently, the nature of the learning environment also affects outcomes. Thus, language change is an evolutionary process that dynamically entails the nature of the learners and the nature of their context. Because the social worlds in which we live vary, the systems of communication that emerge reflect a wide range of natural human languaging.

Within learners and over generations, language evolves as a shared system that is imprecisely replicated as linguistic content is taken up and passed on. The adaptation that is the cumulative effect of transmission is subject to different pressures than the adaptation that occurs within individual learners acquiring their idiolects. While individuals in the process of learning are dynamically interacting with their language models, a language being transmitted over generations does not have access to its previous states, so anything that is not taken up by new learners will not remain in the language. Universal tendencies in languages around the world consequently reflect the tendencies of learners in how they perceive and organize language information, as well as the evolutionary processes of selection and survival (Senghas, 2021).

Conclusions

In sum, language emergence is the consequence of natural tendencies of language learners and universal processes of the evolution of systems. The patterns of emergence of language structure, and of convergence across members of a language community, will depend on several factors regarding the social conditions under which the

language emerges. These include the age of learners, the size of the community, and patterns of contact among members. These social conditions correspond to certain mechanisms of change. The age of learners will affect the learning tendencies that are applied. The size of the peer community will affect the degree of convergence within and across systems. Transmission from one generation to the next will provide opportunities for reanalysis and restructuring. High degrees of shared knowledge may reduce pressure for specificity and conventionalization (e.g., Mudd et al., 2022, Meir et al., 2012). High variability in language models will lead to faster and more substantial changes over time (Kocab et al., 2019). And so on. Some of these factors have begun to be uncovered and considered in the context of historical studies of language emergence and studies of small signing communities in the present day. Power and Meier (2023) provide detailed demographic information about the age and language experiences of the earliest students at the American School for the Deaf, considered central to the emergence and growth of ASL in the 1800s. Continued, and especially comparative, research into these factors will likely lead to a more refined understanding of the ways they interact with each other to shape language emergence and change.

Every language community in the world lies at a unique intersection of demographic factors and social interaction patterns. Our work on the emergence of Nicaraguan signing represents one opportunity to study how different conditions are combining to propagate language. The wide variety of situations around the world will allow us to link the diverse aspects of social communities to the nature of languages that emerge within them. We can examine each intersection where the seed of language is planted and watch what grows.

Notes

1. Hou (2020, 2024) documents the signing practices of multigenerational homesigning families in Oaxaca, Mexico, who have regular contact with other peer-aged homesigners as well as those older and younger than themselves. Horton (2020) documents another multigenerational homesigning family in Nebaj, Guatemala. German (2024) reports on an emergent homesign system used among three deaf siblings in Zinacantán, Mexico.

Reed (2022) describes a different situation in Western Highlands, Papua New Guinea, where individual deaf homesigners communicate with hearing signers, thus forming a "regional sign network" such that homesigners' systems may influence and resemble one another without individual homesigners ever coming into contact. All of these cases differ from the situation of the Nicaraguan homesigners we report on here, as the Nicaraguan homesigners in this study have no regular contact with other deaf people.

2. See Flaherty et al. (2023) for additional information about potential changes in the size of the signing space of older and younger LSN signers.

3. Terms used in the sign language linguistics literature, such as *directionality* and *verb agreement*, entail consistent mappings between form and meaning, both within a particular signer, as well as across signers. As we describe the characteristics of LSN, while we are aware of similarities to other languages, we are careful not to assume that any structures we observe serve the same functions or operate in exactly the same ways as apparently similar forms documented previously in other sign languages. Accordingly, we adopt neutral, descriptive terms to describe the forms we observe while gathering information about their distributions and consistency of use within and across individuals. Indeed, as the studies described here show, often the same form is applied to different functions by different members of the LSN signing community. Our neutral terminology should not be taken to imply that any particular variant or idiolect of LSN lacks grammatical functions documented in other languages, such as verb agreement.

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