Abrupt grammatical reorganization of an emergent sign language: the expression of motion in Zinacantec Family Homesign

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Abstract

This study traces the development of discrete, combinatorial structure in Zinacantec Family Homesign ("Z sign"), a sign language developed since the 1970s by several deaf siblings in Mexico (Haviland 2020b), focusing on the expression of motion. The results reveal that the first signer, who generated a homesign system without access to language models, represents motion events holistically. Later-born signers, who acquired this homesign system from infancy, distribute the components of motion events over sequences of discrete signs. Furthermore, later-born signers exhibit greater regularity of form-meaning mappings and increased articulatory efficiency. Importantly, these changes occur abruptly between the first- and second-born signers, rather than incrementally across signers. This study extends previous findings for Nicaraguan Sign Language (Senghas et al. 2004) to a social group of a much smaller scale, suggesting that the parallel processes of cultural transmission and language acquisition drive language emergence, regardless of community size.

Keywords: homesign; sign language; language emergence; combinatorial structure; segmentation; cultural transmission; acquisition; expression of motion

1 Introduction

This study examines the emergence of a basic design feature of language—discrete, combinatorial structure (Hockett 1960, Kirby et al. 2008, Tamariz & Kirby 2016)—in Zinacantec Family Homesign ('Z sign'), an emergent sign language developed over the past four decades by three deaf siblings and their hearing family members in Zinacantán, a Tsotsil (Mayan) speaking community of Chiapas, Mexico (Haviland 2011, 2020b). Z sign has its origins in a homesign system developed by the first deaf member of the family to communicate with her hearing caregivers. As additional deaf siblings and other hearing relatives were born into the family, they acquired this homesign system from infancy. Consequently, the original homesign system of the first deaf individual expanded into a more complex sign language shared by the family. I show in this paper that as the homesign system was transmitted from the first deaf signer to later-born family members, there was an increase in the use of sequential combinations of discrete units, and a decrease in the use of holistic, non-combinatorial forms. Furthermore, later-born signers exhibit increased regularity of form-meaning mappings and increased articulatory efficiency. I attribute these changes to the ability of children to re-organize and regularize inconsistent linguistic input (Austin et al. 2022, Newport 1988, Schuler et al. 2021, Senghas 2021, Senghas et al. 2004, Singleton & Newport 2004).

The centrality of discreteness and combinatoriality is apparent in the linguistic expression of motion. Events of motion are comprised of several components, including a moving figure, a stationary ground with respect to which the figure moves, a path trajectory along which the figure moves, and a manner of motion. In real-world events of motion, these components unfold simultaneously. However, in linguistic expression these components are typically encoded sequentially, i.e. in separate lexical items (Talmy 1991). For instance, in the English sentence 'The bottle floated out of the cave', 'the bottle' represents the figure, "floated" represents the manner of motion, 'out of' represents the path, and 'the cave' represents the ground Talmy 1991: 488. While there are certain exceptions (see Section 2), the tendency to encode events of motion sequentially is apparent both in spoken and signed languages (Supalla 1990).

A crucial question is how languages came to be structured around combinations of discrete units. To address this question, one might compare stages of an existing language at different points in time. Historical linguistics is traditionally concerned with diachronic change in fully established spoken languages. These languages are used by relatively stable communities of speakers in which the language is maintained across countless generations in an unbroken chain of cultural transmission. Children in these communities acquire the language on the basis of input provided by adult speakers and same-age peers, and there is typically a close match between the language of one generation and that of the next. However, minor cross-generational differences arise with each transmission, resulting in incremental grammatical change (Labov 2007). This kind of gradual diachronic change can be directly observed to the extent that a language is attested in historical documents. Alternatively, earlier forms of a language can be reconstructed via comparison of presently attested, related varieties. However, comparative reconstruction can only go so far; diachronic studies do not typically endeavor to trace language change back to the very origins of a language. Indeed, because most extant spoken languages have been transmitted across countless generations, extending back into prehistory, their earliest forms are seemingly unrecoverable.

The opportunity to observe the earliest forms of a language arises only when the chain of cultural transmission is broken, that is, when the language of one generation is not successfully passed along to the next, and as a result the younger generation must develop a new language. Thus, in recent decades there have been an increasing number of studies of emerging sign languages, created by communities of deaf individuals who have extremely limited knowledge of or access to any existing signed or spoken languages (Brentari & Goldin-Meadow 2017, Meir et al. 2010). Sign languages often have their origins in homesign systems—idiosyncratic sign systems created by linguistically isolated deaf children (Goldin-Meadow & Feldman 1977). Once a critical mass of deaf individuals gathers to form a community, their respective homesign systems may coalesce into a new, shared language (Meir et al. 2010, Senghas & Coppola 2001). Studies of emerging sign languages provide the opportunity to answer such questions as: What grammatical structures are present (or absent) in a communication system developed without input from conventional language models? How do members of a nascent linguistic community converge upon a shared, conventional grammar? How does the process of cultural transmission impact the structure of an emergent sign language?

The effects of transmission have been examined in several emergent sign languages. Compared to older generations of signers, younger generations of signers exhibit greater structural regularity and complexity, especially in the domains of morphosyntax (Padden et al. 2010, Sandler et al. 2005, Senghas & Coppola 2001, Senghas et al. 2004), sub-lexical phonology (Brentari et al. 2021, Sandler et al. 2011a) and prosody (Sandler et al. 2011b). However, there is conflicting evidence concerning the rate at which structure emerges. For instance, findings on Nicaraguan Sign Language indicate that there was an abrupt reorganization of linguistic structure as the language was transmitted from the first to second cohorts of signers (Senghas & Coppola 2001, Senghas et al. 2004). On the other hand, data from Al-Sayyid Bedouin Sign Language point to a more gradual emergence of structure that proceeds incrementally over the course of multiple generations of signers (Padden et al. 2010, Sandler et al. 2011a,b).[1] It may be that sociolinguistic factors—differences in the demographics of the signing community (e.g., total population size, the ratio of deaf signers to hearing signers, the density of social networks among signers, etc.), the setting in which the language developed (an urban school versus a rural village), and the typical age at which deaf individuals are first exposed to sign language—influence the rate and trajectory of language emergence. To clarify the role of these factors, data from sign languages developing in a diverse range of sociolinguistic settings are required.

This study aims to describe and quantify differences among the Z signers by examining the expression of manner and path of motion. Specifically, I ask whether the Z signers conflate these elements in the same sign, as in gesture and homesign (Özyürek et al. 2015, Senghas et al. 2004), or distribute them across a sequence of discrete signs, as in fully-developed languages (Supalla 1990, Talmy 1991). By comparing how each of the signers represents motion events, I aim to trace the emergence in Z sign of discrete, combinatorial structure. The results of this study provide evidence for abrupt grammatical change brought about by the transmission of the Z sign from the first-born signer to the second-born and subsequent signers. These results parallel the findings for Nicaraguan Sign Language but extend them to a social group of a much smaller scale, indicating that the transmission of language to children drives language emergence, regardless of the size of the linguistic community.

2 The expression of manner and path in established and emergent sign languages

Sign languages exhibit greater potential for simultaneity in the expression of motion than do spoken languages due to the affordances of the visual modality (Aronoff et al. 2005, Klima & Bellugi 1979, Loos et al. 2022, Meier 2002, Vermeerbergen et al. 2007). Simultaneous structure is well-documented in classifier (CL) predicates (Emmorey 2003, Zwitserlood 2012), which are composed of multiple morphemes that encode figure, ground, path, and manner Supalla (1982). For instance, to describe a vehicle moving along a downward path in a spiral fashion, a signer of American Sign Language (ASL) could produce the CL in (1). The handshape specifies the semantic class of the figure (VEHICLE), the overall displacement of the hand through

[1] Differences in the how a "cohort" of NSL signers versus a "generation" of ABSL signers is defined likely influence how researchers interpret the rate of diachronic change in each language.

space indicates the path (DOWNWARD), and an additional spiraling motion of the hand as it moves downward indicates manner (CIRCLE). In this example, all components of the event are encoded in the phonological parameters of the CL, which are produced simultaneously.

(1) American Sign Language (Supalla 1990: 129)

CL:VEHICLE-CIRCLE-DOWNWARD
vehicle-move.in.circle-downward

'A vehicle spirals downwards.'

Despite this enhanced potential for simultaneity, the tendency towards segmentation of manner and path is still apparent among sign languages. Supalla (1990) noted that ASL signers often employ constructions comprised of a manner verb followed by a path verb, which he analyzed as a type of serial verb construction. Similar constructions have since been attested in many other sign languages, including Sign Language of the Netherlands (Couvee & Pfau 2018, Slobin & Hoiting 1994), Adamorobe Sign Language (Nyst 2007), Hong Kong Sign Language (Tang & Yang 2007), Argentinian Sign Language (Benedicto et al. 2008), and Catalan Sign Language (Benedicto et al. 2008). Typically, the path verb is a CL, while the manner verb often takes the form of constructed action (CA) (Cormier et al. 2015, Metzger 1995, Quinto-Pozos 2007a,b, Winston 1991). CA refers to the signer's use of his or her own body to enact the "actions, utterances, thought, attitudes, or feelings of one or more referents" (Cormier et al. 2015: 167). Stated informally, CA involves "becoming the referent". For instance, an example of a serial verb construction in Hong Kong Sign Language is given in (3) below. In this example, the manner of motion 'running' is encoded via CA (CA:RUN), realized as a pumping action of the arms, an action that is typically performed while running. The path trajectory 'in a circle' is encoded via a CL (CL:HUMAN-RUN-IN-A-CIRCLE).

(2) Hong Kong Sign Language (Tang & Yang 2007: 1230)

FATHER	*CA:RUN*	*CL:HUMAN-CIRCLE*
father	run	human-move.in.circle

'Father runs in a circle.'

The cross-linguistic correspondence between path and CL, on the one hand, and manner and CA, on the other, is likely due to the distinct scales of representation that each employs. A CL maps the referent onto the signer's hand. To encode the path trajectory of the referent, the signer simply moves their hand through space. However, the anatomical details of the referent (its facial expression, movements of the limbs, etc.) are not encoded in most CL.[2]Thus, the amount of manner information that can be encoded in a CL is limited. By contrast, CA involves a mapping of the referent onto the signer's body. This enables the signer to represent the bodily actions of referents in a more direct, efficient, and transparent manner than is possible with lexical signs or CL, which typically do not encode the details of the referents bodily actions. CA is therefore a more direct means of representing manner of motion than CL. However, given

[2]One exception is the 'legs' CL handshape, which represents the two legs of a person or animal via the index and middle fingers. Manner of locomotion, namely 'walking', can be conveyed by wiggling the fingers. This CL is attested in many sign languages, including Z sign (Figure 7).

that the referent is mapped onto the signer's body, the signer would have to physically move her body through space to encode the referent's path trajectory. This strategy is possible and is in fact attested in highly performative registers of signing, such as when narrating a story on stage to an audience of children (Quinto-Pozos & Mehta 2010). Nonetheless, outside of overtly performative contexts, native signers indicate that the inclusion of path information in CA is unacceptable (Supalla 1990). Thus, in the expression of motion in signed languages, CL and CA play complementary roles of encoding path and manner, respectively.

By contrast, hearing non-signers, when asked to produce gestural representations of motion events, typically conflate manner and path in the same gesture, regardless of whether these gestures are produced with or without concurrent speech (Özyürek et al. 2015, Senghas et al. 2004). The contrast between gesture and sign language in this regard reinforces the claim that discreteness and combinatoriality are fundamental to language: even though the visual modality makes simultaneous expression possible, signers nonetheless exhibit a tendency to encode manner and path of motion sequentially.

2.1 The expression of manner and path in homesign and emergent sign languages

Over 90% of deaf children are born to hearing parents who do not sign, and as a result receive delayed exposure to language (Mitchell & Karchmer 2004). A deaf child who cannot hear spoken language and who has not been exposed to a conventional sign language may generate an idiosyncratic homesign system to communicate with those around him or her (Goldin-Meadow & Feldman 1977). Homesign systems exhibit many, but not all, of the structural properties of conventional languages: stable lexicons (Goldin-Meadow et al. 1994), hierarchical structure at the levels of the word (Goldin-Meadow et al. 1995) and sentence (Goldin-Meadow 1982), regular constituent order (Goldin-Meadow 1987), and strategies for negation and question formation (Franklin et al. 2010). Crucially, the structural properties of homesign systems are not present in the gestures produced by the hearing caregivers of deaf children (Goldin-Meadow & Mylander 1990), and despite significant cross-cultural variation in the frequency and complexity of caregiver gesture, there does not appear to be variation in the complexity of homesign systems developed by children from different cultures (Flaherty et al. 2021). These findings indicate that the language-like properties of homesign systems are generated by the children themselves.

In the expression of motion, homesign systems represent an intermediate stage between gesture and fully-developed language. Homesigners from different cultures have been shown to produce gestures that encode either manner alone or path alone, suggesting that they are capable of segmenting out each element (Zheng & Goldin-Meadow 2002). However, they do not consistently combine these individual manner and path gestures into larger strings, but instead employ holistic gestures in which manner and path are conflated, much like gesturers (Özyürek et al. 2015). This is not to say that homesign is identical to gesture: unlike the gesturers, homesigners often add an additional manner or path gesture in sequence with the conflated manner+path form. Özyürek et al. (2015) suggest that the combination of conflated manner+path gestures and individual manner or path gestures represents the initial stage of language-like segmentation that begins only once a manual communication system is maintained over an extended period of time, as is the case with homesign.

Segmentation continues to develop as an emerging sign system is transmitted to new generations of deaf children. Nicaraguan Sign Language (NSL) emerged when deaf children were brought together at a school in the late 1970s (Senghas & Coppola 2001). Having formed a community at the school, the children began to generate a sign language. As later cohorts of children enrolled at the school, the sign language grew increasingly more complex in several domains of grammatical structure Senghas & Coppola (2001), Senghas et al. (2004). For instance, Senghas et al. (2004) examined the expression of motion in NSL and in the co-speech gestures of hearing Nicaraguans (which are a potential source of input for the emergent sign language). The gestures of hearing Nicaraguans as well as the signing of the initial cohort of deaf children lacked segmentation of manner and path, that is, both groups exhibited a strong tendency to conflate manner and path in a single gesture or sign (e.g., ROLL+DOWN). By contrast, the second and third cohorts of deaf children who enrolled at the school exhibited the opposite tendency: they distributed manner and path information over a sequence of discrete signs (e.g., ROLL, DOWN), much as users of established spoken and sign languages do. Senghas et al. interpret these cross-cohort differences as a transition from a holistic, gesture-like stage to a more language-like stage characterized by discrete, combinatorial structure. They argue that young children exhibit biases for analytical structure and linear sequencing that drive them to break down holistic forms into their component parts and re-combine them in a more systematic fashion.

3 Zinacantec Family Homesign

Zinacantec Family Homesign (Z sign) is an emergent sign language developed by a single extended family from Zinacantán, a Tsotsil (Mayan) speaking community of in the highlands of Chiapas, Mexico (Haviland 2020b). None of the Z signers have met other deaf people or signers of any other sign language. Thus, Z sign developed without external influence from any other language, except possibly spoken Tsotsil by way of the hearing signers. The family tree in Figure 1 displays all seven fluent Z signers, identified by pseudonyms and their ages at the time of data collection. Z sign originated with the first deaf individual in the family, Jane, born in 1976 (Haviland 2011). Unable to hear the spoken Tsotsil of the household, Jane began to develop a homesign system that she used to communicate with those around her. In 1982, another deaf sibling, Frank, was born. The final deaf sibling, Will, was born in 1988, twelve years after Jane. None of the deaf signers has acquired any spoken Tsotsil or Spanish, and they are not literate in either language. In addition to three deaf signers, four hearing members of the family have grown up with Z sign as a home language. Terry is a hearing sister of the deaf siblings, born in 1987, who reportedly began to sign before she began to speak (Haviland 2011). Rita is a niece of the four signing siblings and thus acquired Z sign from early infancy. The next hearing signer is Jane's son, Vic, who acquired Z sign from birth. Finally, Rita's daughter Pat has grown up with Z sign and has become a proficient signer.

Research on Z sign was initiated by John Haviland in 2008. Haviland's research has shed light on some of the emergent grammatical properties of Z sign, including morphological and syntactic means of distinguishing nouns from verbs (Haviland 2011, 2013c), spatial language (Haviland 2013a), the grammaticalization of gestures and facial expressions drawn from the hearing community (Haviland 2019), and the role of eye gaze in turn-taking (Haviland 2020a). Additionally, Haviland has examined the sociolinguistics of the Z sign community. For instance, the Z signers have strong beliefs about what constitutes "correct" signing and who in the family has the authority to enforce norms of sign usage (Haviland 2013b, 2016). Specifically, the Z

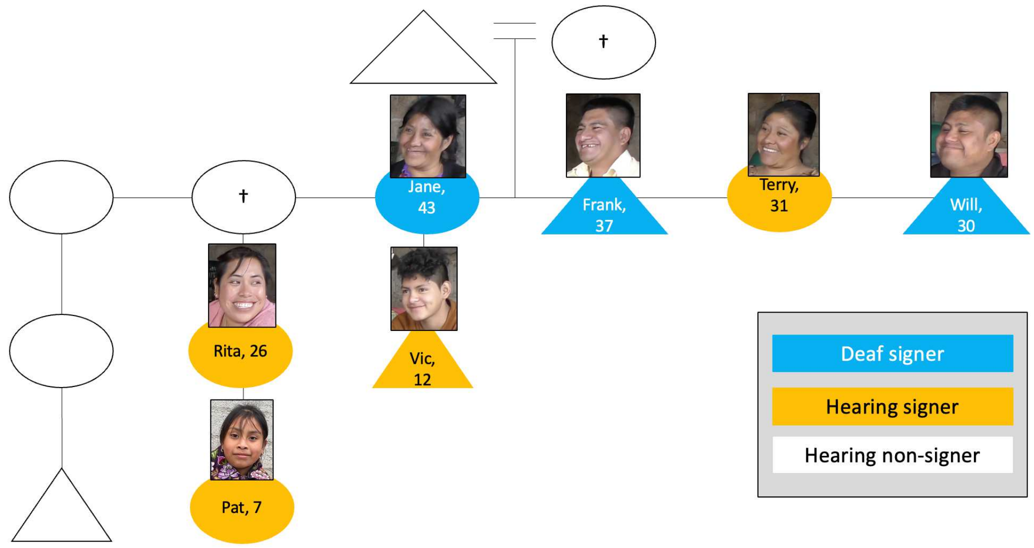

Figure 1: The signers of Zinacantec Family Homesign (Z sign) as of 2019.

signers frequently express that Jane's signing differs from their own, and her signing is often subject to heated critique (Haviland 2013b, 2016). The later-born signers' intuition that the eldest deaf sibling's signing differs from their own signing suggests that Z sign has undergone change since its origins as Jane's childhood homesign system.

It is worth considering the origins of Z sign from the perspective of the individual deaf signers. Jane, as the first deaf individual of the family, had neither adult sign models nor signing peers who could provide her accessible linguistic input. Thus, she effectively developed her homesign system in the absence of linguistic input, as many deaf children born into non-signing families do (Goldin-Meadow & Feldman 1977). Although an older sibling's homesign system cannot be characterized as 'conventional' linguistic input (i.e. language produced by adults who are proficient in the language), Frank at least would have had the benefit of exposure to Jane's signing. Will, the third deaf sibling, had the richest language learning environment of all: not only did he have Jane and Frank as signing models, but he also had a hearing sister Terry, only a year his senior, as a signing peer. The central question of this study is whether these differences in the amount of input (estimated in terms of the number of language models) each signer had in early childhood influences the structure of their signing. Indeed, evidence from other emerging sign systems arising in a variety of social settings indicates that input from older signers as well as interaction with signing peers can impact the development of structure (Gagne 2017, Horton 2018, Hou 2016). Thus, I assume in this study that the language of each Z signer reflects the learning environment in which he or she was immersed as a child, and that any differences between elder and younger signers can be taken as distinct diachronic stages in the development of Z sign.

4 Methodology

The data for this study were collected in 2019 over the course of six consecutive weeks of fieldwork. During that time, the author lived with the study participants in their home. The participants in this study are six of the seven Z signers. The youngest signer, Pat, did not participate in data collection. Narratives were elicited from the signers using two wordless picture books and video clips from three different cartoons. The picture books were 'the Frog Stories' (Mayer 1967, 1969), which are widely employed in typological studies of motion (Slobin 2004). The cartoon video clips included the Canary Row cartoon, which is commonly used in studies of gesture and sign language (McNeill 1992, Senghas et al. 2004), and two other similar cartoons. Elicitation was carried out with two participants at a time so that the signer was always addressing another signer. The participants' responses were coded in ELAN (Wittenburg et al. 2006) for (a) segmentation strategies (Section 6.1), (b) the types of signs used to express motion (Section 6.2), and (c) the use of different articulators to encode path (Section 6.3).

5 Motion expressions in Z sign

To contextualize the quantitative results presented in Section 6, I illustrate the use of CA and CL in Z sign with examples from the narrative data. I first present five different signers' representations of the same motion event to demonstrate the most common means of encoding manner and path among the Z signers. The motion event comes from the Canary Row cartoon: Sylvester the Cat climbs up a gutter pipe to reach the windowsill where Tweety Bird is caged. Two additional examples, based on other motion events, are presented to show two less common strategies of representing manner and path.

In Figure 2, Terry represents 'climbing' via CA. She adopts the role of the protagonist and moves her hands in an alternating up-and-down motion, as if climbing. This alternating motion of the hands represents the manner of motion, but no path trajectory is represented since the hands move relative to a single point in space. By contrast, in Figure 3, Rita uses a CL to describe the cat climbing up a gutter pipe. She uses her right hand to represent the cat as it moves along an upward trajectory; her left hand represents the stationary the pipe. She does not mention the manner of motion 'climbing'.

Figure 2: Use of CA to represent manner only.

Figure 3: Use of a CL to represent path only.

In the following three examples, the signers represent both manner and path, but they differ in whether they do so simultaneously or sequentially. In Figure 4, Jane represents 'climbing up' by producing an alternating motion of her hands, as if climbing, while at the same time displacing her hands along an upward trajectory. Thus, in Jane's representation, manner and path are represented simultaneously. In Figure 5, Frank begins the same way as Jane—with a simultaneous representation of manner and path—but follows it up with a separate path sign. Frank's rendition of this motion event thus exhibits both simultaneity and sequentiality. These 'mixed' forms are attested in Turkish homesign systems (Özyürek et al. 2015) and in Nicaraguan Sign Language (Senghas et al. 2013). Finally, in Figure 6, Will represents path and manner in an entirely sequential fashion: he begins by representing path via a CL, and then represents manner via CA. These sequential combinations of CA and CL resemble the serial verb constructions attested in established sign languages (see Section 2).

Figure 4: Use of CA to represent manner and path simultaneously.

The five examples above illustrate the most common strategies for representing motion events in the narrative data. There are two additional strategies that occurred at a lower frequency. The first is the use of the 'legs' CL to represent manner and path simultaneously, which involves the use of the index and middle fingers to represent the legs of a referent. The fingers can be wiggled back-and-forth to represent the manner of motion 'walking'. In Figure 7, Rita uses the 'legs' CL to represent a duck walking along a linear path.

Figure 5: Use of a sequence of CA to represent manner and path simultaneously, followed by a CL to represent path.

Figure 6: Use of a sequence of a CL followed by CA to represent manner.

The final type of motion expression involves the use of CA to encode path without encoding manner. These examples involve a specific type of CA known as "handling constructions" whereby the signer configures his or her hand as if manipulating an object. In Figure 8, Terry describes a clip in which the cat grabs the bird and then takes off running. She produces with her right hand a handling construction for the cat's grasping of the bird, and then displaces that hand along a path trajectory. Thus, though Terry has assumed the role of the cat, she does not enact his manner of motion; she merely represents his manipulation of the bird and the path along which the two referents move.

In sum, the Z signers use CL to encode path and sometimes manner+path, but not manner alone; they use CA to encode manner, path, or manner+path; and they also combine CL and CA in the same expression to represent manner and path sequentially. However, not all strategies occur with equal frequency, nor are they distributed evenly across all Z signers. I support these claims with quantitative data in the following section.

Figure 7: Use of a CL to represent manner and path simultaneously.

Figure 8: Use of CA (specifically, a handling construction) to represent path.

6 Quantitative Results

A total of 666 expressions of motion were identified in the elicited narratives, representing 194 distinct events of motion. The number of motion expressions produced by each signer ranged from 80 to 153 (Mean = 111 expressions per signer, SD = 23.1). In section 6.1, I examine the rate at which the Z signers employ holistic versus segmented representations of manner and path of motion. In section 6.2, I examine the consistency with which the Z signers map these components of motion onto distinct types of signs. Finally, in section 6.3, I examine the use of the hands versus the body in the expression of path.

6.1 Segmentation of manner and path

Following Özyürek et al. (2015), motion expressions were assigned one of five codes that indicate whether manner and path are expressed and how they are segmented. The first two codes correspond to one-component expressions in which either manner or path is conveyed, but not both. The latter three codes correspond to two-component expressions in which both manner and path are expressed (referred to as manner+path expressions). Each expression type is illustrated in Section 5.

1. Manner-only: the signer represents manner but not path. (Figure 2)

2. Path-only: the signer represents path but not manner. (Figures 3 and 8)
3. Conflated: the signer represents both manner and path in a single sign. (Figures 4 and 7)
4. Sequenced: the signer represents manner and path in separate signs. (Figure 5)
5. Mixed: the signer produces a sequence of a Conflated sign and a manner-only or path-only sign. (Figure 6)

Of the 666 motion expressions in the dataset, there were 86 Manner-only expressions, 356 Path-only expressions, and 224 manner+path expressions. In this section, we examine only the manner+path expressions since we are interested in the extent to which the Z signers express manner and path simultaneously versus sequentially.

Of the 224 manner+path expressions, there were 146 Sequenced expressions, 47 Conflated expressions, and 31 Mixed expressions. Thus, overall the Z signers strongly prefer Sequenced expressions, that is, to express manner and path in separate signs. Notably, the later-born signers produced far more Sequenced expressions than Conflated expressions; Jane is the only signer who produced more Conflated expressions than Sequenced expressions. In fact, nearly half (22/47) of all Conflated expressions in the data were produced by Jane. Table 1 displays the number of Conflated, Sequenced, and Mixed expressions produced by each signer; these data are represented as proportions in Figure 9. A Pearson's chi-squared test of homogeneity revealed that the distribution of Conflated, Mixed, and Sequenced expressions differs significantly across the six signers (χ^2 (10, N = 226) = 35.42, $p < .001$). In order to identify outliers in the data, standardized residuals were calculated using Monte Carlo simulation with 10,000 replicates. The residual for Jane's production of Conflated expressions falls +4.8 standard deviations below the mean, and the residual for her production of Sequenced expressions falls -5.2 standard deviations above the mean. Using the standard threshold of ±3.0 standard deviations, these values can be considered statistical outliers, indicating that the distribution of Conflated and Sequenced forms in Jane's signing differs from that of the other signers. Thus, when both components are expressed, Z signers prefer to express them in separate signs. The first-born deaf signer, Jane, is the exception: she is the only signer whose dominant strategy is to express manner and path simultaneously in a single, holistic sign.

Table 1: The number of Conflated, Sequenced, and Mixed Manner+Path expressions produced by each signer. Statistical outliers are marked with an asterisk. Signers' ages and hearing status are provided in parentheses.

	Conflated	**Sequenced**	**Mixed**	**Total**
Jane (43, deaf)	22*	15*	7	44
Frank (37, deaf)	3	28	4	35
Terry (31,hearing)	7	24	5	36
Will (30, deaf)	2	20	2	24
Rita (26, hearing)	3	30	8	41
Vic (12, hearing)	11	30	5	46

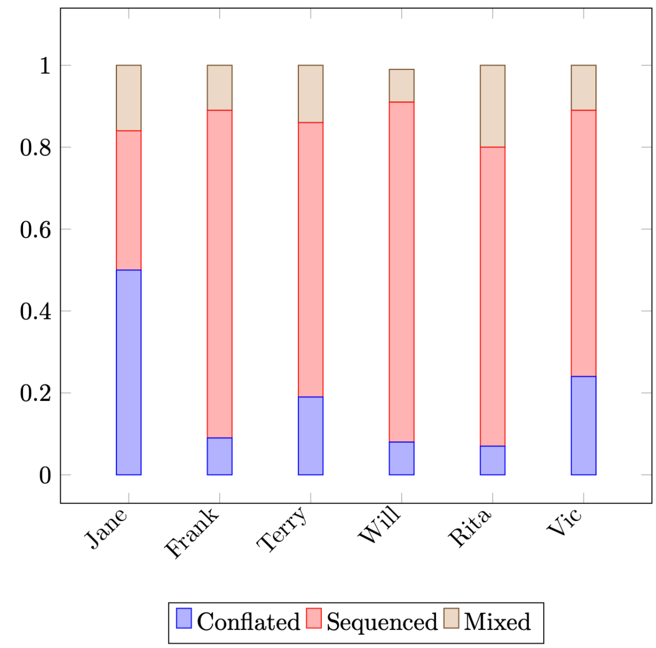

Figure 9: The proportion of Conflated, Mixed, and Sequenced Manner+Path expressions produced by each signer.

6.2 Form-meaning mappings

In this section, I explore how consistently the Z signers map form to meaning. Given the observed differences between Jane and the later-born signers in the use of holistic versus segmented representations, it is likely that Jane also differs in how consistently she uses different strategies for encoding path and manner. Recall from Section 2 that in established sign languages there is an association between CA and manner, on the one hand, and between CL and path, on the other. Thus, each motion expression in the dataset was coded for the presence of CA, CL, or both (CA+CL). The decision to code a sign as CA or CL was based on whether the referent was mapped onto the signers' whole body or only the hand. A sign was coded as CA when the signer adopted the perspective of a referent and used his or her own body to represent the actions of that referent (e.g., Figure 2). A sign was coded as CL when the signer used his or her hand to represent the referent's motion through space (e.g., Figures 3 and 7).

6.2.1 Classifier Predicates

Table 2 displays the number of CL tokens produced by each signer that encodes information about manner only, path only, or manner+path; these data are represented as proportions in Figure 10. Averaging across signers, 98% (SD = 1%) of CL tokens encode path only and 2% (SD = 1%) encode manner+path. There are no CL tokens that convey manner only. Thus, the Z signers have established a consistent mapping of CL onto path, and there is virtually no variation across signers in this respect. The rare exception is the use of the legs classifier which encodes manner ('walking') simultaneously with path via a wiggling movement of the index and middle fingers (see Figure 7).

Table 2: The number of CL tokens that represent manner, path, or both. Signers' ages and hearing status are provided in parentheses.

	Manner-only	Path-only	Manner+Path	Total
Jane (43, deaf)	0	61	1	62
Frank (37, deaf)	0	88	2	90
Terry (31, hearing)	0	128	2	130
Will (30, deaf)	0	62	1	63
Rita (26, hearing)	0	102	3	105
Vic (12, hearing)	0	62	0	62

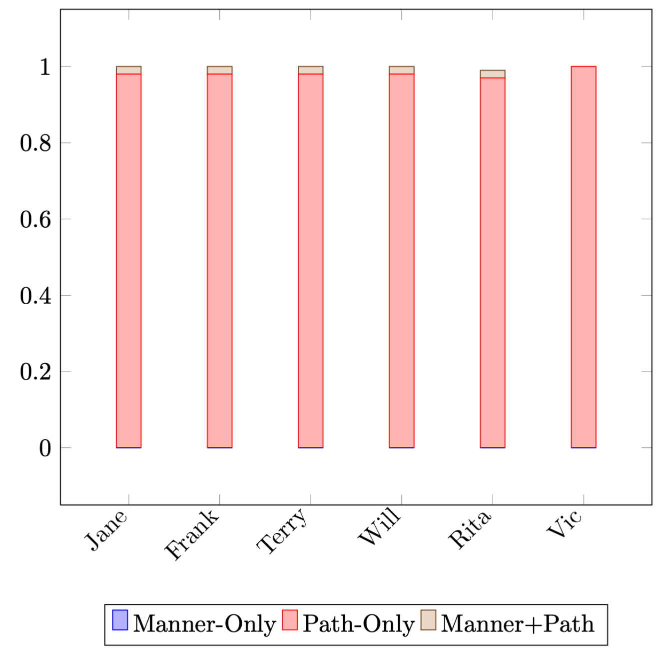

Figure 10: The proportion of CL tokens produced by each signer that encodes manner, path, or both.

6.2.2 Constructed Action

Table 3 displays the number of CA tokens produced by each signer that encodes information about manner only, path only, or manner+path; these data are represented as proportions in Figure 11. Averaging across signers, 74% (SD = 12%) of CA tokens encode manner only, 8% (SD = 5%) encode path only, and 18% encode manner+path (13%). Thus, there appears to be less consistency and more variation across signers in the use of CA compared to the use of CL. Notably, nearly half (44%) of CA tokens that encode manner+path were produced by Jane, and an additional quarter of them (25%) were produced by Jane's son, Vic. A Pearson's chi-squared test of homogeneity revealed that the distribution of CA tokens that encode manner only, path only, or manner+path differs significantly across the six signers (χ^2 (10, N = 324) = 48.77, p < .001). In order to identify outliers in the data, standardized residuals were calculated using Monte Carlo simulation with 10,000 replicates. The residual for Jane's production of Manner-only forms falls -4.2 standard deviations below the mean, and the residual for her production of

Manner+Path forms falls +5.7 standard deviations above the mean. Using the standard threshold of ±3.0 standard deviations, these values can be considered statistical outliers, indicating that the distribution of Manner-only and Manner+Path forms in Jane's signing differs from that of the other signers. Thus, Jane is more likely than other signers to convey include a Path component in CA.

Table 3: The number of CA tokens that represent manner, path, or both. Statistical outliers are marked with an asterisk. Signers' ages and hearing status are provided in parentheses.

	Manner-only	**Path-only**	**Manner+Path**	**Total**
Jane (43, deaf)	31*	2	28*	61
Frank (37, deaf)	45	2	4	51
Terry (31, hearing)	37	8	5	50
Will (30, deaf)	35	1	3	39
Rita (26, hearing)	37	7	8	52
Vic (12, hearing)	50	5	16	71

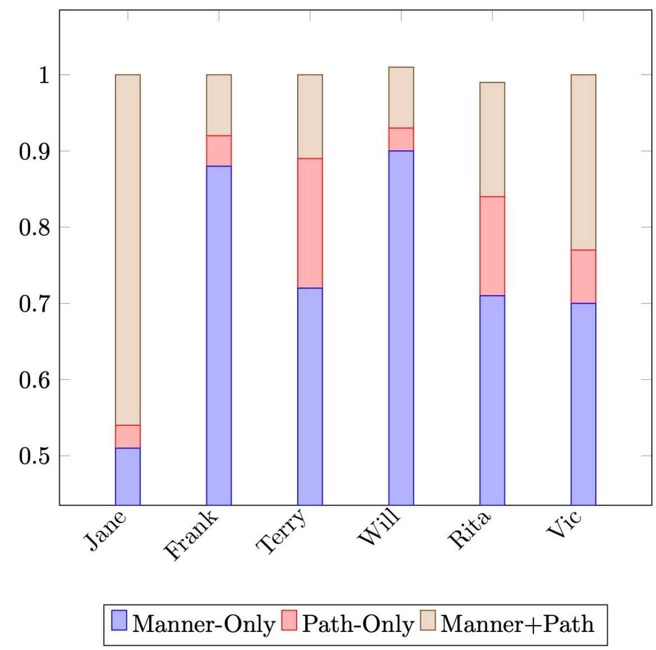

Figure 11: The proportion of CA tokens produced by each signer that encodes manner, path, or both.

To summarize the findings for form-meaning mapping, the Z signers uniformly use CL to encode path. However, the signers differ in the use of CA. Whereas the later-born signers consistently use CA to encode manner, Jane variably uses CA to encode manner or manner+path. Thus, with respect to the use of CA, Jane's mapping of form to meaning is inconsistent. This corresponds to Jane's reliance on conflated (holistic) representations, as observed in Section 6.1.

6.3 Use of the hands versus the body in the representation of path

Thus far, we have examined the expression of path in terms of formal categories of signs (CA and CL) based on whether the referent is mapped onto the signer's entire body or only the signer's hand. However, these broad classifications obscure important articulatory considerations. Though CA entails that the referent be mapped onto the signer's body, the whole body is not necessarily moved along the path trajectory. In some CA forms, path is conveyed by moving the hands only, as in Figure 4 when Jane represents 'climbing up' by enacting a climbing motion with her hands while also displacing her hands along an upward path trajectory. In other instances of CA, the signer may also move the upper and/or lower body in the expression of path. For instance, in Figure 12, Jane represents 'walking from one point to another' by actually shifting her whole body, including her feet, along the floor.

Figure 12: Jane moves her entire body along the path trajectory.

This whole-body strategy is typically reserved for performative contexts in established sign languages (Quinto-Pozos & Mehta 2010). By contrast, it is not uncommon for Z signers to produce whole-body signs, both in the narrative data reported here and in spontaneous conversation. The question we now address is whether all Z signers are equally likely to employ the body in the expression of path. Each CA token was assigned one of the following codes:

1. Path-body: the signer moves his or her torso and/or feet along the path trajectory.
2. Path-hands: the signer moves only his or her hands along the path trajectory.
3. No Path: the signer does not represent the path trajectory.

Table 4 displays the number of CA tokens coded as Path-body, Path-hands, and No Path; these data are represented as proportions in Figure 13. Averaging across signers, 72% (SD = 13%) of CA tokens were coded as No Path, 16% (SD = 7%) were coded as Path-hands, 13% (SD = 11%) were coded as Path-body. Thus, the majority of CA tokens do not convey any path information. When path information is included in CA, it is slightly more likely to be represented by moving only the hands as compared to moving the torso and/or lower body. Out of all the Z signers, Jane is the most likely to move her body along the path trajectory. In fact, Jane produced 49% of CA tokens coded as Path-body. The later-born signers Frank, Terry, Will, and Rita each produced five or fewer Path-body forms. Vic, Jane's son, produced 11 Path-body forms. A Pearson's chi-squared test of homogeneity revealed that the distribution of CA tokens coded as Path-body, Path-hands, or No Path differs significantly across the six signers (χ^2 (10, N = 324) = 46.72, $p < .001$). In order to identify outliers in the data, standardized residuals were calculated using Monte Carlo simulation with 10,000 replicates. The residual for Jane's production of Path-body forms falls +5.4 standard deviations above the mean, and the residual for her production of No-Path forms falls -3.9 standard deviations below the mean. Using the standard threshold of ±3.0 standard deviations, these values can be considered statistical outliers, indicating that the distribution of Path-body and No Path forms in Jane's signing differs from that of the other signers. That is, Jane is more likely than other signers to represent Path by moving her body through space.

Table 4: The number of CA tokens with a path movement realized by the body, the hands, or no path movement. Statistical outliers are marked with an asterisk. Signers' ages and hearing status are provided in parentheses.

	Path-body	**Path-hands**	**No Path**	**Total**
Jane (43, deaf)	21*	9	31*	61
Frank (37, deaf)	2	4	45	51
Terry (31, hearing)	5	12	33	50
Will (30, deaf)	1	3	35	39
Rita (26, hearing)	3	13	36	52
Vic (12, hearing)	11	10	50	71

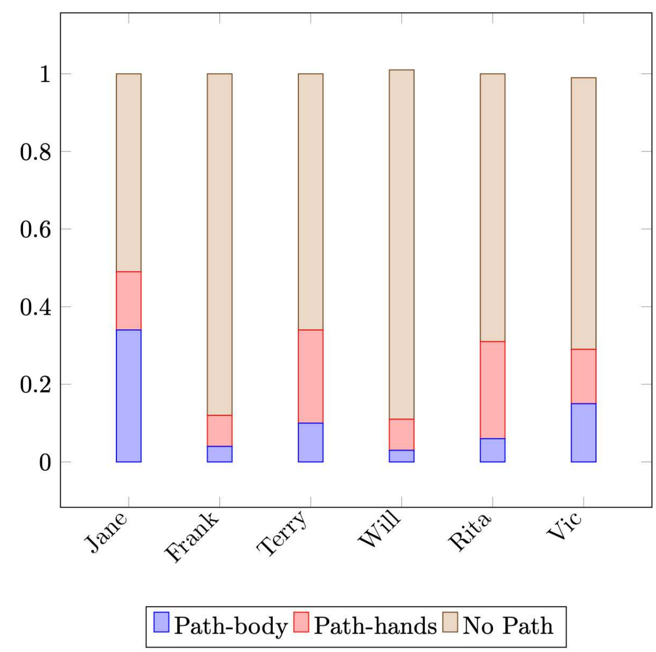

Figure 13: The proportion of CA tokens with a path movement realized by the body, the hands, or no path movement.

7 Discussion

The first-born Z signer, Jane, differs systematically from later-born signers in three respects. First, Jane tends to represent motion events in a holistic fashion. By contrast, the later-born signers represent motion events with sequential concatenations of discrete signs. Second, Jane maps form to meaning in an unpredictable fashion: while she consistently uses CL to encode path, she uses CA variably to encode either manner or manner+path. The later-born signers, however, are consistent in using CL to encode path and CA to encode manner. Third, Jane frequently relies on whole-body enactments of motion events, whereas later-born signers primarily represent motion by moving the hands through space, representing an increase in articulatory efficiency. I argue that these differences are due to changes introduced into Z sign by the later-born signers as they acquired Jane's original homesign system in infancy. Rather than merely reproduce the input to which they were exposed—a system based on holistic representations, variable form-meaning mappings, and effortful whole-body forms—they reorganized it, introducing increased combinatoriality and consistency, while also decreasing the articulatory effort required to produce these forms. In this section, I expand upon the nature of these changes and relate the findings of this study to previous work on language acquisition, language emergence, and diachronic change in signed languages.

7.1 Tradeoffs between iconicity, combinatoriality, and ease of articulation

The findings of this study suggest that there is a tradeoff between iconicity, on the one hand, and combinatoriality and ease of articulation on the other. The observed differences between Jane and the later-born signers represent a reduction in iconicity in two senses. First, the shift away from holistic forms toward segmented forms means that the simultaneity of manner and path is no longer represented. That is, holistic forms more closely mirror the structure of actual events of motion, which unfold in a simultaneous fashion. Segmented forms do not convey this simultaneity, and therefore represent motion events in a more abstract fashion. The abrupt shift from holistic forms in Jane's signing to segmented forms in the signing of the later-born signers closely resembles the transformation that Nicaraguan Sign Language underwent as it was transmitted from the first to subsequent cohorts of deaf children (Senghas et al. 2004). As Senghas et al. argue, this process of segmentation bolsters the expressive power of the system: whereas holistic representations involve a single mapping of one gesture onto the entire event, segmented representations involve multiple mappings of separate gestures onto the different components of the event. Thus, segmented representations allow the signer to home in on individual event, e.g., to refer to path without mentioning manner or vice versa. Once signers are able to refer to event components individually, they can designate different grammatical devices for the expression of each component, such as CA for manner and CL for path, leading to greater consistency in mapping form to meaning. In this way, the tendency of children to "divide, re-combine, and re-map" the forms and meanings provided in the input is a crucial mechanism for language change (Senghas 2021). Notably, studies of artificial languages based on an iterated learning paradigm (Kirby et al. 2008) also report a trade-off between iconicity and combinatoriality both in whistle-based (Roberts et al. 2015) and visual-symbol based (Verhoef et al. 2016) artificial languages. These studies show that when iconicity is intentionally supressed, learners are more likely to rely on sequential combinations of discrete units as the language is transmitted across generations of learners. Therefore, in order for combinatorial structure to emerge, signers must (at least partially) be able to abstract away from iconicity.

The second reduction in iconicity can be observed in the transition away from encoding path with the body to encoding path with the hands. In CA, there is a direct correspondence between the body of the referent and the body of the signer, which allows the signer to show precisely what the referent does. Thus, to represent path, the signer must move her body along the path trajectory. This strategy closely preserves the life-size scale of the original motion event. By contrast, the representation of motion events via manual CL involves a greater degree of abstraction away from the original motion event. The referent's body corresponds not to the signer's body, but only to the signer's hand. Accordingly, the signer represents path by moving her hand through space. This entails that the signer must scale down the event and map it onto the signing space in schematic form. Thus, alternating between CA for manner and CL for path requires the integration of two different scales of representation, one that is life-sized and another that is miniaturized. Deaf children acquiring an established sign language master life-sized representations earlier than reduced-scale representations, possibly because the latter are more abstract (Schick 1987). The findings of this study suggests that this developmental sequence is mirrored in language emergence.

Studies of historical change in established sign languages have also observed an erosion of iconicity over time (Frishberg 1975). Frishberg noted that lexical signs of ASL that have an iconic origin are today arbitrary in form. She argued that this reduction of iconicity was motivated by articulatory and perceptual ease. For instance, lexical content is restricted to the hands. Whereas early 20th century ASL signs sometimes involved movements of the head, in modern ASL those movements are carried out by the hands. The argument here is that it is articulatorily simpler to concentrate lexically significant movements to the hands, rather than to have them distributed across different bodily articulators. Similarly, Sanders Napoli (2016) observe that signs that induce incidental movements of the torso are underrepresented in the lexicons of three unrelated sign languages (two established and one emergent), likely because moving the torso requires more articulatory effort than moving the hands. Along similar lines, I argue that the scarcity of whole-body forms in the signing of the later-born Z signers, compared to their relative abundance in the signing of the first-born signer, Jane, is a change motivated by articulatory and perceptual ease. On the part of the signer, it requires much more effort to move the torso or legs than to move only the hands. On the part of the addressee, it requires more effort to attend to both the upper and lower body than to attend to the upper body alone. Thus, like in established sign languages, a diachronic shift away from iconicity is apparent in Z sign. What is most striking about these findings is that the effects of articulatory pressure are appreciable even at the earliest stages of language emergence.

7.2 The role of cultural transmission and the rate of emergence

As noted in the introduction, there is conflicting evidence as to whether linguistic structure emerges abruptly or gradually. The results of this study provide evidence of abrupt grammatical change. In all three aspects of the expression of motion examined in this study, the first-born deaf signer, Jane, differs from all later-born signers. Consider the differences between Jane, the first-born signer, and Frank, the second-born signer, in the expression of manner and path. The distribution of segmentation strategies in Jane's signing is 50% Conflated, 34%

Sequenced, and 16% Mixed. By contrast, the distribution of segmentation strategies in Frank's signing is 9% Conflated, 80% Sequenced, and 11% Mixed. Remarkably, this is nearly identical to the distribution of strategies in the signing of Will, the third deaf sibling: approximately 8% Conflated, 83% Sequenced, and 8% Mixed. The striking differences between the first- and second-born signers, contrasted with the close similarity of the second- and third-born signers, indicate that the shift from primarily Conflated forms to primarily Sequenced forms occurs abruptly, beginning with second-born signer Frank, rather than occurring in incremental steps across signers. These results parallel the cross-cohort differences among signers of Nicaraguan Sign Language (Senghas et al. 2004), suggesting that it is children's acquisition of an emergent sign system that results in a reorganization of its structure. Importantly, the NSL and Z signing communities differ considerably in size and setting, and therefore also in the amount of input available to child learners. NSL emerged among a relatively large, school-based community of signers, whereas Z sign emerged among seven members of an extended family living in the same household. Thus, the differences between first-born Jane and second-born Frank suggest that the homesign system of an older sibling serves as sufficient input to support the development of language-like segmentation. In line with studies of deaf children acquiring signed language from non-native signing parents (Newport 1988, Singleton & Newport 2004) and artificial learning studies comparing child learners to adult learners (Austin et al. 2022, Schuler et al. 2021), the results of this study show that children are able to transform highly irregular and inconsistent input into a regular grammatical system.

What explains the abrupt nature of the observed changes to Z sign? I appeal here to the idea that transmission of a linguistic system from older learners to younger learners, along with cognitive biases that constrain language acquisition, ensures that languages are learnable (Christiansen & Chater 2008, Zuidema 2002). The most relevant learning biases for this study are a preference for compositionality (Kirby et al. 2008, Kirby & Hurford 2002, Roberts et al. 2015, Senghas et al. 2004, Verhoef et al. 2016) and a preference for regularity (Christiansen & Devlin 1997, Sandler et al. 2005). Linguistic forms that go against these biases (i.e. those that involve non-compositional representations and irregular mappings of form to meaning) are harder to learn and therefore are less likely to be successfully acquired by learners of the next generation. In this way, language structure is shaped by learners, therefore ensuring that it is maximally learnable. With respect to Z sign, I argue that the signing of first-born signer, Jane, represents a communication system that is relatively difficult to learn given that it relies on holistic forms in which the mapping of form to meaning is variable. The signing of the second-born signer, Frank, represents a system that has been filtered through constraints on language learning. The result is a system that is easier to learn, has enhanced expressive power, and requires minimal articulatory effort: it relies on combinations of discrete units, each with a predictable meaning, produced primarily by the hands. The lack of significant differences among the later-born signers confirms that the changes introduced by Frank resulted in a learnable system.

7.3 Deaf signers versus hearing signers

It is worth noting that the hearing signers appear to be slightly less consistent than the two later-born deaf signers (though there are no statistically significant differences among them). A potential explanation for this is that the hearing signers do not use Z sign as their primary modality; rather, Z sign is instead their secondary modality that they use only in communication with their deaf relatives. Vic in particular bears more similarity to Jane than other signers, possibly because he is Jane's son and has thus likely spent more time interacting directly with her than with other signers (see (Haviland 2022) and Horton et al. (Horton et al. Forthcoming) regarding Vic's socialization into Z sign). Furthermore, unlike the adult signers who grew up signing together, Vic does not have any same-age deaf peers with whom to sign. Thus, the hearing signers' more limited use of Z sign may cause their signing to diverge from that of the deaf signers. Similarly, the effects of a lack of a peer signing network are apparent in hearing native signers of NSL, who acquired the language from deaf parents (Gagne 2017). Nonetheless, in terms of segmentation, consistency of form-meaning mapping, and articulatory efficiency, the hearing signers do pattern more like the later-born deaf signers than the first-born signer Jane. This is to be expected, given that the hearing signers all were exposed to Z sign from infancy.

8 Conclusion

This study has described the transformation of what began as idiosyncratic homesign system, largely based on holistic, gesture-like representations, into a shared sign language structured around productive combinations of discrete units. I have argued that the transmission of Jane's original homesign system to the later-born signers has driven the observed changes, influenced by the following learning biases in language acquisition and general pressures on linguistic structure. First, children exhibit a strong tendency to produce analytic forms, even when presented with input characterized by simultaneous structure. Second, children are capable of constructing a regular grammar on the sole basis of unusually inconsistent or unpredictable input. Third, the general pressure for the communicative signal to be articulatorily efficient leads to a reduction in iconicity, which further scaffolds the emergence of combinatoriality. This study extends previous findings on language emergence and contributes to our understanding of the mechanisms underlying language change.

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Abbreviations

ASL American Sign Language
CA Constructed Action

CL Classifier predicate
NSL Nicaraguan Sign Language
HKSL Hong Kong Sign Language

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Résumé

Cette étude examine le développement de la structure combinatoire discrète dans le Zinacantec Family Homesign (« Z sign »), une langue des signes développée depuis les années 1970 par plusieurs frères et sœurs sourds au Mexique (Haviland 2020b), en se concentrant sur l'expression du mouvement. Les résultats révèlent que la première signeuse, qui a généré une langue des signes sans accès aux modèles de langage, représente les événements de mouvement de manière holistique. Les signeurs nés plus tard, qui ont acquis cette langue des signes dès la petite enfance, répartissent les composants des événements de mouvement sur des séquences de signes discrets. De plus, les signeurs nés plus tard présentent une plus grande régularité des correspondances forme-sens et efficacité articulatoire accrue. Il est important de noter que ces changements se produisent brusquement entre la première signeuse et le deuxième signeur, plutôt que progressivement entre les signeurs. Cette étude étend les résultats précédents pour la langue des signes nicaraguayenne (Senghas et al. 2004) à un groupe social plus petit, suggérant que le parallèle les processus de transmission culturelle et d'acquisition de la langue sont à l'origine de l'émergence de la langue, quelle que soit la taille de la communauté.

Zusammenfassung

Diese Studie untersucht die Entwicklung einer diskreten, kombinatorischen Struktur im Zinacantec Family Homesign („Z sign“), einer Gebärdensprache, die seit den 1970er Jahren von mehreren gehörlosen Geschwistern in Mexiko (Haviland 2020b) entwickelt wurde und sich auf den Ausdruck von Bewegung konzentriert. Die Ergebnisse zeigen, dass der erste Gebärdensprachler, der eine Gebärdensprache ohne Zugang zu Sprachmodellen generierte, stellt Bewegungsereignisse ganzheitlich dar. Später geborene Gebärdensprachler, die diese Gebärdensprache von Kindesbeinen an erworben hat, verteilt die Komponenten von Bewegungsereignissen auf Sequenzen diskreter Zeichen. Darüber hinaus weisen später geborene Gebärdensprachler größere Werte auf Regelmäßigkeit der Form-Bedeutungs-Zuordnungen und erhöhte Artikulationseffizienz. Wichtig ist, dass diese Veränderungen abrupt zwischen den erst- und zweitgeborenen Gebärdensprachler auftreten und nicht schrittweise zwischen den Gebärdensprachler. Diese Studie weitet frühere Erkenntnisse zur nicaraguanischen Gebärdensprache (Senghas et al.

2004) auf eine kleinere soziale Gruppe aus und legt nahe, dass die parallelen Prozesse der kulturellen Weitergabe und des Spracherwerbs die Entstehung von Sprachen vorantreiben, unabhängig von der Größe der Gemeinschaft.

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