Research Article

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Diachronic changes the Nicaraguan sign language classifier system: Semantic and phonological factors

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Abstract: This article presents an exploration of the usage and distribution of the 1-handshape classifier (Cl-1) and the 2-handshape classifier (Cl-2), both diachronically and synchronically, tracking classifier development in a detailed dataset of Nicaraguan individual homesigners and two groups of Nicaraguan Sign Language signers. Both phonological and semantic dimensions are analyzed in service of discerning what factors impact the choice and phonological production of the relevant classifiers. Phonologically we find that the distribution of Cl-1 and Cl-2 is quite different than would be expected were articulatory complexity the main motivating factor. We suggest also that this dataset is a microcosm of the system as a whole, and patterns of 1-handed and 2-handed signs vary across groups. Semantically, we find that (1) classifier use is more semantically restricted among individual homesigners. (2) As classifiers become more semantically frequent and flexible in the earliest cohort of Nicaraguan signers, constraints on production emerge. (3) Vertical transmission of those classifiers and constraints leads to more flexible usage in subsequent cohorts.

Keywords: classifier, classifier handshape, Nicaraguan sign language, LSN, American sign language, ASL, homesign, language emergence, language development

1 Introduction

Classifier predicates in sign languages are a subset of signs used to describe motion or localization of events. Every parameter of the sign has the potential to carry its own significance. The classifier handshape may communicate the morphosyntactic or semantic class of the referent, e.g., person, small animal, vehicle, etc. The motion, manner, and direction of the sign iconically represent the actions or states of the described event (Supalla 1982, Liddell and Johnson 1989, Benedicto and Brentari 2004).

Research by Supalla (1982) laid foundational work in understanding the structural and functional aspects of American Sign Language (ASL) classifiers. Supalla demonstrated how classifiers are used to convey complex information about motion and spatial relationships, providing a framework for analyzing these elements in other sign languages. Later work has found this complexity to be consistent cross-linguistically;[1] Brentari et al. (2015), and Emmorey (2003) have compared classifier systems across different sign languages as well as the

1 Adamarobe Sign Language (AdaSL) was previously reported not to have classifiers (Nyst 2010); however, later work has challenged this view (Edward 2021, Nyst et al. 2022).

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mental structures of the users of those languages respectively, finding complex patterns in the argument structure of classifier predicates across multiple sign languages and demonstrating the heightened spatial processing abilities of users of ASL, which allow them to employ a type of mental spatial framework. This framework and the visuospatial modality of sign language allow for their application to these complex classifier systems. Moreover, the interaction between classifiers and other grammatical elements has been a focal point in more recent studies (Gökgöz 2024). This research underscores the multi-functional nature of classifiers, serving not only as descriptive tools but also as integral components of sign language syntax and morphology, suggesting that even at the earliest stages of language emergence, we are likely to find evidence of systematization of classifiers (Goldin-Meadow 2003, Brentari et al. 2012). This early structuring serves to further emphasize the inherent tendency of sign languages to develop organized and rule-governed systems even in their nascent forms.

In the context of emerging sign languages – community sign languages generated from individual homesigner input with limited or no input from other sign languages – these ur-classifier systems play a significant role in the emergence process. Over apparent time, we are able to observe those classifiers and the broader classifier systems of those languages as they continue to develop. As this article relates to community-level language change among linguistic cohorts, the term *language emergence* is used to describe this early stage of community level language being derived from individual homesigner input. *Language development* is used to describe an increase in complexity and systematization at that community level, rather than development within an individual.

Research has shown that as Nicaraguan Sign Language (LSN) evolved, the use of classifiers became more sophisticated, reflecting the language's increasing grammatical complexity (Brentari 2012, 2017, Goldin-Meadow et al. 2015). This development mirrors the broader linguistic processes observed in other sign languages and reaffirms the near universality and importance of classifiers in sign language grammar.

Despite their complexity, classifiers are often approached as largely iconic. The resemblance between the form of the sign and its meaning is particularly evident in classifier constructions, with iconicity in classifiers serving to provide a direct visual representation of the physical and spatial characteristics of the referent (Emmorey and Herzig 2003, Taub 2001). This iconic relationship is critical as it enhances the descriptive power of sign languages, allowing signers to convey complex information efficiently and effectively (Emmorey 2003). Research has also shown that iconicity in classifiers plays a crucial role in language acquisition and cognitive processing (Caselli et al. 2021, Gappmayr et al. 2022). Studies suggest that the iconic nature of classifiers aids in learning and remembering signs, as the visual similarity between the sign and its referent facilitates cognitive mapping (Bosworth and Emmorey 2010, Caselli and Pyers 2017). This is particularly significant in the early stages of sign language acquisition, both for native signers and second-language learners (Ortega et al. 2014, Ortega and Morgan 2015). Despite its critical role, the degree of iconicity can vary a great deal across different sign languages and even among individual signers. While iconicity does provide initial learning benefits, sign languages inevitably evolve to incorporate more arbitrary elements over time, lexicalizing more gestural elements and balancing iconicity with linguistic efficiency and expressiveness (Cormier et al. 2012, Levshina and Moran 2021, Slonimska et al. 2022, Zwitserlood 2012). It is the more arbitrary elements of classifiers that our study explores.

Since several different classifier handshapes might be used for the same entity, we want to explore the motivations of classifiers used for the same entity, but in different contexts. One motivation for the distribution of classifiers might be the phonological context. Another relevant context is semantic. We therefore address two questions with this work: (1) Does the complexity of the overall resulting phonological structure constrain the choice of classifier (or properties of classifiers)? (2) Do specific formal meanings, such as volitionality, or combinations of meanings, constrain the choice of classifiers (or properties of classifiers)?

In this article, we analyze a dataset of narrative retellings of the eight shorts of the Warner Bros. Cartoon 'Canary Row' (Freleng 1949). Characters referenced by signers include, in order of appearance, Sylvester – a cat attempting to capture Tweety, Tweety – a pet canary, Tweety's owner Granny, a hotel bellhop, an organ grinder, and the organ grinder's monkey. We examine the changes that have occurred in the use of two classifiers for 'person' in Nicaraguan groups of signers using the apparent historical time method (Labov 1994).

We have also included data from a corpus of ASL signers' Canary Row narratives, processed using an identical procedure. It is critical for researchers to take pains to avoid treating ASL as an endpoint or goal for emerging languages, and we caution readers against that interpretation of our results. However, the field's familiarity with ASL can make it a valuable reference group for comparison and orientation to statistical results, and it is presented here to that end.

2 Background

2.1 LSN

LSN exemplifies a rare phenomenon in the study of language emergence and development. Its origins can be traced back to the late 1970s and early 1980s, when the government in Nicaragua established special education programs for deaf children. Prior to these programs, deaf individuals primarily utilized individual homesign systems – personal gesture systems typically developed within individual families. The congregating of these children in educational settings allowed for the interaction of these individual homesign systems, leading to horizontal transmission of signs and the spontaneous creation of a new, shared sign language (Coppola 2021, Polich 2005).

The initial phase of LSN's development was characterized by the contributions of the first cohort of signers (Cohort One, referred to as LSN1), consisting of older children and adolescents. These individuals brought their personal homesign systems into a communal environment, thereby engaging in horizontal transmission. This nascent stage of LSN featured basic grammatical structures and simplified syntax, as documented in numerous studies (Senghas et al. 2004, Senghas and Coppola 2001).

As younger children, forming the second cohort (Cohort Two, referred to as LSN2), entered the educational programs, they were afforded the opportunity to learn LSN from first-cohort signers. This vertical transmission allowed these LSN2 signers to introduce further linguistic innovations, resulting in more complex grammatical features and a richer language structure. Research has shown that the second cohort contributed significantly to the linguistic complexity of LSN (Senghas 2003, Senghas and Coppola 2001). The progression and refinement of LSN has been well-documented, affording linguists a look at the dynamic nature of language development and the role of human interaction in shaping linguistic systems (Coppola 2021).

The creation of a new sign language in Nicaragua over the past five decades offers us the opportunity to observe the earliest stages of conventionalization of classifier predicates as they emerge. Before the 1970s, deaf Nicaraguan individuals had little contact with one another (Kegl and Iwata 1989, Polich 2005, Senghas et al. 2004, Coppola and Brentari 2014, Coppola and Newport 2006, 2021, Brentari et al. 2012, Goldin-Meadow et al. 2015). Since the earliest days of LSN research, the participation of these three groups – individual homesigners, LSN1 and LSN2 – has been critical to our understanding of the emergence of the grammar of this language.

Homesigner: An individual homesigner is a deaf individual who has not been exposed to a conventional sign language and instead develops a unique system of gestures and signs to communicate with those around them, typically their immediate family. These individuals come from diverse social situations, and as such, it is impossible to present an all-encompassing description of their backgrounds. In the current study, all homesign participants would be most accurately characterized as *individual homesigners* – users of a linguistic system created by a single deaf individual – rather than users of family or communal homesign system (Goico and Horton 2023). In individual homesign contexts, these systems are created independently, within each household, and are not shared across a broader community. The majority of deaf individuals in Nicaragua are not part of a signing community and do not know LSN. Due to a variety of social, geographic, and financial obstacles, they do not attend a deaf school or regularly interact with other deaf people. Individual homesigners represent the initial stage of language development, providing the raw material necessary for gesture systems to coalesce into a more standardized form of communication when these individuals are brought together (Coppola and Newport 2005, Goldin-Meadow 2003, 223–5).

Cohort One: Cohort One (LSN1) refers to the first group of children who were brought together in the newly established special education programs for the deaf in Nicaragua in the late-1970s and early-1980s. These individuals, who had developed their own individual homesign systems, began to interact and form a communal sign language. Their combined gestural inputs and communicative needs led to the creation of the earliest form of LSN. This cohort laid the foundational grammatical and lexical structures of the emerging sign language (Senghas 1995, Kegl 1999).

Cohort Two: Cohort Two (LSN2) is made up of the children who joined the Nicaraguan special education programs in the mid-1980s to the early-1990s. These children learned LSN from the first cohort and, in doing so, introduced further innovations and complexities into the language.

Their contributions included the refinement of grammatical rules and the expansion of the linguistic repertoire. The linguistic input from LSN1, combined with the natural language acquisition processes for the younger LSN2 signers, resulted in a more structured and sophisticated sign language, showcasing a clear developmental progression among stages of language development (Senghas and Coppola 2001, Senghas 2003). Subsequent cohorts have been developing LSN utilizing the same mechanisms as LSN2, by interacting with members of their own cohorts as well as those of previous cohorts (Coppola 2021).

2.2 Concepts under investigation

Whole-entity classifiers in manual modality languages are a type of classifier representing an entire object or entity rather than its parts or specific attributes (Engberg-Pedersen 1993). This type of classifier uses a specific handshape that semantically corresponds to the general category of the referent, such as a human, vehicle, or small animal. The primary phonological elements of the classifier handshape at issue include the selected fingers, joint configurations, and the possible hand-internal movement of those joints. Both of the handshapes that are the target of these investigations are whole entity classifiers:

Cl-1 classifiers: Cl-1 () classifiers are characterized by the extended index finger pointing upwards. Morphologically, this handshape can refer to a variety of elongated items, but here only tokens in which the handshape represents the upright human torso and is used to denote anthropomorphic referents, including humans and fictional human-like animals, are considered. It iconically depicts the general form and posture of an upright human figure (Supalla 1986). Morphologically, these forms will be referred to as Cl-1, and phonologically, these forms will be referred to as the '1-handshape,' which refers specifically to the selected finger group using the index finger.

Cl-2 classifiers: Cl-2 () classifiers are characterized by the extended index and middle fingers pointing downwards. Morphologically, this handshape represents the legs of an anthropomorphic figure and is used to denote similar referents to Cl-1, including humans and fictional human-like animals. The two fingers iconically depict the general form and movement of the legs (Brentari 2019, Emmorey 2003). Morphologically, these forms will be referred to as Cl-2, and phonologically, these forms will be referred to as the '2-handshape,' which refers specifically to the selected finger group using the spread index and middle fingers.

2.3 Variations upon the two primary handshapes

Horizontal ('h'; e.g., ): Horizontal handshapes are those in which the active part of the hand (i.e., the palm side of the finger) is oriented parallel with the plane of movement. A horizontal classifier need not be produced horizontally. Within our dataset, horizontal classifiers were regularly used to indicate Sylvester's climb up a drainpipe. Because the plane of movement (i.e., supporting surface, the drainpipe) runs vertically, the motion must track in parallel with that of the supporting surface (i.e., vertically) in order to be considered a horizontal production of the classifier.

Bent ('b'; e.g., ): A bent handshape is one which includes any discernible bend in the proximal interphalangeal joints (PIP, the middle finger joint), or distal interphalangeal joints (DIP, the joint closest to the fingertip).[2] This categorization excludes the slight bending that occurs passively when the hand is inactive.

Stacked ('k': e.g., ): In a stacked handshape, the fingers are not in the same plane. In Mandel's (1981) dissertation, he refers to the fingers as 'stair-stepped' or 'differentially extended;' by definition, this variation is only relevant to the Cl-2.

Movement ('m': e.g.,   ): Hand-internal movement is defined as any increase or decrease in the angle of the metacarpophalangeal joints (MCP, or knuckle joint), PIP, or DIP, over the course of the production of the sign.

Based on previous work on the phonological structure of signs alone, we might predict that because the handshape of Cl-1 has a generally simpler structure (see Brentari 1998, Engberg-Pedersen et al. 2025), it would (i) be more frequent overall (Battison 1978, Eccarius 2008, Hara 2003, Rozelle 2003), (ii) have more subtypes in terms of joints and orientation (Brentari 1998), and (iii) occur more frequently in 2-handed signs with different handshapes, since it can also appear on the non-dominant hand (Battison 1978, Eccarius and Brentari 2007).

From the perspective of semantics, the notion of *volitionality* will be important for the analyses that follow, as it is the characteristic we will be tracking among cohorts and the notion relevant to the development of LSN over apparent historical time (Labov 1994). For our purposes, volitionality refers to the characteristic of a referent in a predicate indicating whether the referent intended to perform the action or, in the case of stative classifier predicates, intended to be in a particular state or location (Dowty 1991, Jackendoff 1992, Van Valin 2005).

In the case of predicates demonstrating motion or action, the notion of volitionality can be quite intuitive; Sylvester climbing the inside of a drainpipe would be considered volitional, as this was his intended action; however, Sylvester falling down that same drainpipe would be considered non-volitional. Stative classifiers, on the other hand, can be much less intuitive. Our annotation criteria defined volitionality in a stative classifier as being characterized by the actions that brought a referent to their location. Sylvester standing on a windowsill would be annotated as volitional, as the actions bringing him to that location were his own and performed intentionally. Sylvester sitting in a pile of garbage, after having been thrown out of the building, would be annotated as non-volitional, as the actions bringing him to that location were not his own and were performed without intention on his part.

Based on an analysis of ASL and Danish Sign Language (DTS) (Engberg-Pedersen et al. 2025), we hypothesize that there will be an association between (i) the volitionality of the referent and the choice of the classifier, and (ii) the use of hand-internal movement.

3 Methods

Data for this study were collected through elicited retellings of eight episodes from the animated Warner Bros. cartoon 'Canary Row'. Participants were drawn from four distinct linguistic populations: Nicaraguan individual homesigners, LSN1, LSN2, and ASL users. These participants provided narratives that allowed for an in-depth analysis of classifier usage across different stages of LSN development.

While our focus will be on the Nicaraguan groups, we will be comparing specific points of LSN statistical data with comparable data from ASL – a language with a much longer history (Power 2022, Power and Meier 2023) – as an orientation point to the data provided. Our intention is not to present ASL as a goal or endpoint for recently emerged languages, but it can be a valuable point of reference and is presented here as such.

Because the statistical methods used for the phonological and semantic analyses differ, descriptions can be found in Sections 4.1 and 4.2, respectively.

2 A bend in the metacarpophalangeal joint is necessary for formation of the Cl-2 in most cases; therefore, flexion of the MCP was not considered sufficient for a token to be annotated as bent.

3.1 Populations

Nicaraguan Participants included four individual homesigners (three male, one female; ages 20, 24, 28, and 29), seven LSN1 signers (four male, three female, ages 33–43; year of entry 1974–1982); and five LSN2 signers (three male, two female, ages 21–26; year of entry 1989–1994). All participants were deaf from birth or early childhood, and the LSN2 signers all began signing by the age of 5, typically when they entered school.

ASL Signers: Fifteen ASL signers also participated (nine male, six female; age, 24–67). The narratives were collected in three different data collection periods: 2003, 2006, and 2013. The data from 2003 and 2013 were collected in the Brentari lab, and the 2006 data were collected in the signers' homes. All of the signers were native signers with two deaf parents, or early learners, who acquired ASL before age 5.

3.2 Procedures

Participants were invited to watch the entire Canary Row cartoon. The cartoon was then shown a second time, episode by episode, with intervals for retellings of each episode after each episode was shown. The retellings were carefully recorded for subsequent analysis, ensuring that the natural signing behaviors of the participants were preserved. For individual homesigners, the task involved explaining the plot of each episode to a family member or friend who was familiar with the individual homesigner's system, reflecting the naturalistic context in which individual homesign systems typically operate. Participants from LSN1, LSN2, and ASL interacted with either another member of their cohort or a researcher. All procedures were held constant, and only interlocutor type – family member, researcher, cohort member – was changed between groups. Importantly, retellings were always presented to an interlocutor rather than directly to the camera, maintaining the interpersonal dynamics of natural signed communication. This methodological choice aimed to capture authentic language use, providing a more accurate reflection of how classifiers are employed in real-world interactions.

3.3 Annotation

To systematically analyze the use of Cl-1 and Cl-2 classifiers, we employed ELAN (Crasborn and Sloetjes 2008) to annotate the productions of the participants. This tool enabled us to document each token of a Cl-1 or Cl-2 classifier, including variations upon those two primary handshapes, in our datasets. In addition to creating a count of Cl-1 and Cl-2 use for each of our sub-corpora, a collection of factors, ranging from the phonological to the discourse level, was annotated for each occurrence of the two target classifiers: Cl-1 and Cl-2. For the annotation tiers used in this crosslinguistic project, refer to Kimmelman (2025).

We now turn to the phonological and semantic analyses of the variation in the use of Cl-1 and Cl-2. We ask (i) Does the complexity of the overall resulting phonological structure constrain the choice of classifier (or properties of classifiers) – in general, or across LSN cohorts? (ii) Do specific formal meanings, such as volitionality, or combinations of meanings, constrain the choice of classifiers (or properties of classifiers) – in general, or across LSN cohorts?

4 Analyses and results

Following the annotation process, the data relevant to the phonological research question and the semantics question concerning volitionality were analyzed both quantitatively and qualitatively.

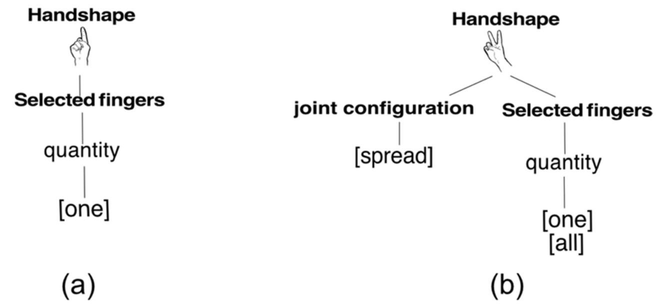

Figure 1: Phonological feature trees in the Prosodic Model (Brentari 1998): (a) the 1-handshape and (b) the 2-handshape.

4.1 Phonological analysis of Cl-1 and Cl-2

The purpose of the phonological analysis is to determine the phonological distribution of the two targeted handshapes for Cl-1 and Cl-2; they will be called '1-handshape' and '2-handshape' to emphasize their status as selected finger groups, not as morphemes. We will address their distribution on the dominant hand alone and in combination with the non-dominant hand as whole signs.

In terms of the analysis of the handshapes themselves, we consider the feature structures needed to capture the 1-handshape and 2-handshape (Figure 1). The phonological structure of the 1-handshape is simpler than that of the 2-handshape.

The two main classes of handshape features (Selected Finger and Joint Configuration) can be divided into low, medium, and high complexity forms (Brentari et al. 2012, 2017). The 1-handshape (Figure 1a) is a low-complexity selected finger group from a structural point of view because it has a non-branching selected finger structure and employs the default 'extended' joint configuration (not shown).[3] In addition to their simpler structural configurations, low-complexity handshapes are the most frequent handshapes cross-linguistically (Hara 2003, Eccarius and Brentari 2007) and are the earliest handshapes acquired by native signers (Boyes Braem 1981). The 2-handshape (Figure 1b) is a medium complexity handshape because it includes an extra finger (and an extra feature), and because the fingers are spread, adding a non-default feature for joint configuration.

For the analysis of 1-handshape's and 2-handshape's participation in two-handed signs, we consider their distribution in Battison's four categories of signs, based on the complexity of their structure (Battison 1978). The categories are as follows: **Type 0** signs are 1-handed signs (e.g., THINK). **Type 1** signs are those in which both hands are active and perform identical motor acts (e.g., MEET). **Type 2** signs are those in which one hand is active (the dominant hand, called 'H1') and one hand is passive (the non-dominant hand, called 'H2'), but both hands have the same handshape (e.g., SIT). **Type 3** signs are those in which H1 moves (active) and H2 is static (passive), and the two hands have different handshapes (e.g., TOUCH). The handshapes that typically appear on H2 are restricted to a few variants of the whole hand or the index finger.[4] These handshapes are called 'unmarked', and all other handshapes 'marked.' Examples of each type of sign are provided in Figure 2[5] (Hulst 1996).

3 Extended is the 'default' joint configuration for a number of reasons; one important one is that if a handshape has only one joint configuration, among all possibilities available, it is most likely to have extended joints (refer to Brentari 1998 for further justification for this designation).

4 There are some exceptions to this set, such as in Hong Kong sign language (Eccarius and Brentari 2007), and Japanese Sign Language (Hara 2003).

5 There are other ways proposed to group signs according to their complexity, particularly van der Hulst (1996). This analysis groups Type 0 and Type 1 signs together as "balanced" in contrast with Type 2 and Type 3, which are "unbalanced." We have used Battison's earlier formulation to be able to refer particularly to all four categories in order to compare Type 0 and Type 3 signs, as the least and most complex types of signs, respectively.

Figure 2: Examples of Battison's types of signs as represented in the data: (a) a Type 0 sign produced by an LSN1 signer (one-handed), (b) a Type 1 sign produced by an LSN1 signer (two-handed, same handshape on H1 and H2, both moving), (c) a Type 2 sign produced by a homesigner, (two-handed, same handshape on H1 and H2, one hand moving) and (d) a Type 3 sign produced by an LSN2 signer (two-handed, different handshapes, one hand moving).

Simpler phonological structures are more frequent across the languages of the world, both signed and spoken (Ladefoged and Maddieson 1996, Brentari 1998, Hara 2003, Rozelle 2003). Based on previous work on the phonological structure of signs alone, we might formulate the following hypotheses:

(1) Hypotheses concerning phonological complexity:

Hypothesis 1: 1-Handshape will be more frequent overall than 2-handshape (Battison 1978, Hara 2003, Rozelle 2003).

Hypothesis 2: 1-Handshape will have more subtypes in terms of joints and orientation than 2-handshape (Brentari 1998).

Hypothesis 3: 1-Handshape will occur more frequently in Type 3 signs than 2-handshape (Eccarius and Brentari 2007).

We know that classifier handshapes interface with the morphology, syntax, and discourse components of the grammar as well, such as the interaction of classifiers with argument structure (Benedicto and Brentari 2004, Gökgöz 2024), causativity (Tang et al. 2018), and viewpoint (Perniss and Özyürek 2008); therefore, other factors besides phonology might influence the choice of handshape. By analyzing data from the Nicaraguan groups and ASL, we can determine how phonological factors are or are not prioritized in classifier choice in a young sign language, and also take a snapshot of the phonological systems of each of the groups – individual homesigners, LSN1 signers, and LSN2 signers. Note that all statistical results are based on the Mann–Whitney U-test of ranked comparisons.

4.1.1 Handshape distribution

First, we examine the 1-handshape and the 2-handshape overall, without consideration of the type of sign in which they occur. We hypothesized that 1-handshape be more frequent overall; however, that is not what we found. Pairwise comparisons across groups revealed no significant differences between pairs of groups for either 1-handshape or 2-handshape. Within-group comparisons showed that LSN1 is the only group with a significant preference, and that is for using 2-handshape (Mann–Whitney U: $U = 0$, $z = -3.0666$, ***$p = 0.0002$) (Figure 3).

Next, we hypothesized that Cl-1 would have more subtypes than Cl-2, so we counted the number of bent, stacked, and moving variants for both 1-handshape and 2-handshape. This hypothesis was not confirmed, as shown in Table 1. In all groups, there are more subtypes of 2-handshape than 1-handshape.

We now turn to the distribution of 1-handshape and 2-handshape in Battison's four types of signs: Type 0, Type 1, Type 2, and Type 3. We start by collapsing across 1- and 2-handshape how often Battison's types appear in the dataset for all of the target groups. The results in Table 2 show that Type 3 signs are the most prevalent, and Type 0 signs are the second most prevalent across all groups in this dataset.

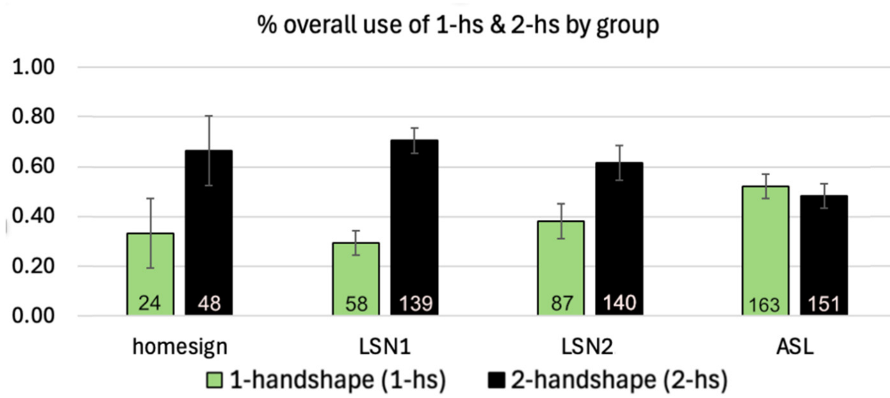

Figure 3: Proportion of 1-handshape (1-hs, green bars) and 2-handshape (2-hs, black bars) across groups (The proportions are calculated by dividing proportion of 1-hs or 2-hs forms by the total of 1hs + 2hs.).

Table 1: Number of subtypes for 1-handshape and 2-handshape across groups

	1-hs sub-types	2-hs sub-types
Homesign	4	7
LSN1	5	9
LSN2	5	9
ASL	6	9

Table 2: Proportions and data points for each of the four types of Battison's sign categories

	Type 0	Type 1	Type 2	Type 3
Homesign	0.14 (*N* = 11)	0.03 (*N* = 2)	0.20 (*N* = 14)	0.63 (*N* = 45)
LSN1	0.31 (*N* = 62)	0.13 (*N* = 26)	0.10 (*N* = 19)	0.46 (*N* = 90)
LSN2	0.24 (*N* = 55)	0.06 (*N* = 15)	0.14 (*N* = 24)	0.56 (*N* = 133)
ASL	0.06 (*N* = 18)	0.05 (*N* = 15)	0.06 (*N* = 19)	0.83 (*N* = 279)

Finally, we turn to the proportion of 1-handshapes and 2-handshapes that are produced in the two most frequent categories in the dataset (Type 0 and Type 3), which are also the categories that are the most distinct – one-handed signs vs two-handed signs that have different handshapes. The results are shown in Figure 4.

The dataset analyzed here can provide insight into the way that Battison's signs are treated in the overall morphophonological system, even though it addresses only 2 classifier handshapes. First, since there are differences across populations, we can infer that the degree to which Battison's sign types are active in a relatively new language, such as LSN, can vary; we count the number of handshapes that are marked (i.e., they are *not* from the set of 'unmarked' handshapes typically found on H2) BASCO15. The homesigners use 'marked' handshapes more often than the other populations (homesigners: 17, LSN1: 5, LSN2: 18, and ASL: 1). This indicates that the restrictions on Type 3 two-handed signs are not as strong as they are in LSN groups or in ASL.

The phonological profile of each of these groups in the current analysis offers insights into the use of morphophonology, and we see that phonology alone will not explain the distribution of the 1-handshape and 2-handshape as classifiers. Returning to the hypotheses in (1), we find that even though previous work has shown that the 1-handshape is more frequent than the 2-handshape across the whole lexicon (Battison 1978, Hara 2003, Rozelle 2003), this is not the case in this classifier dataset. We must therefore be cautious not to overgeneralize from this small classifier dataset to the whole classifier system or to the whole lexicon.

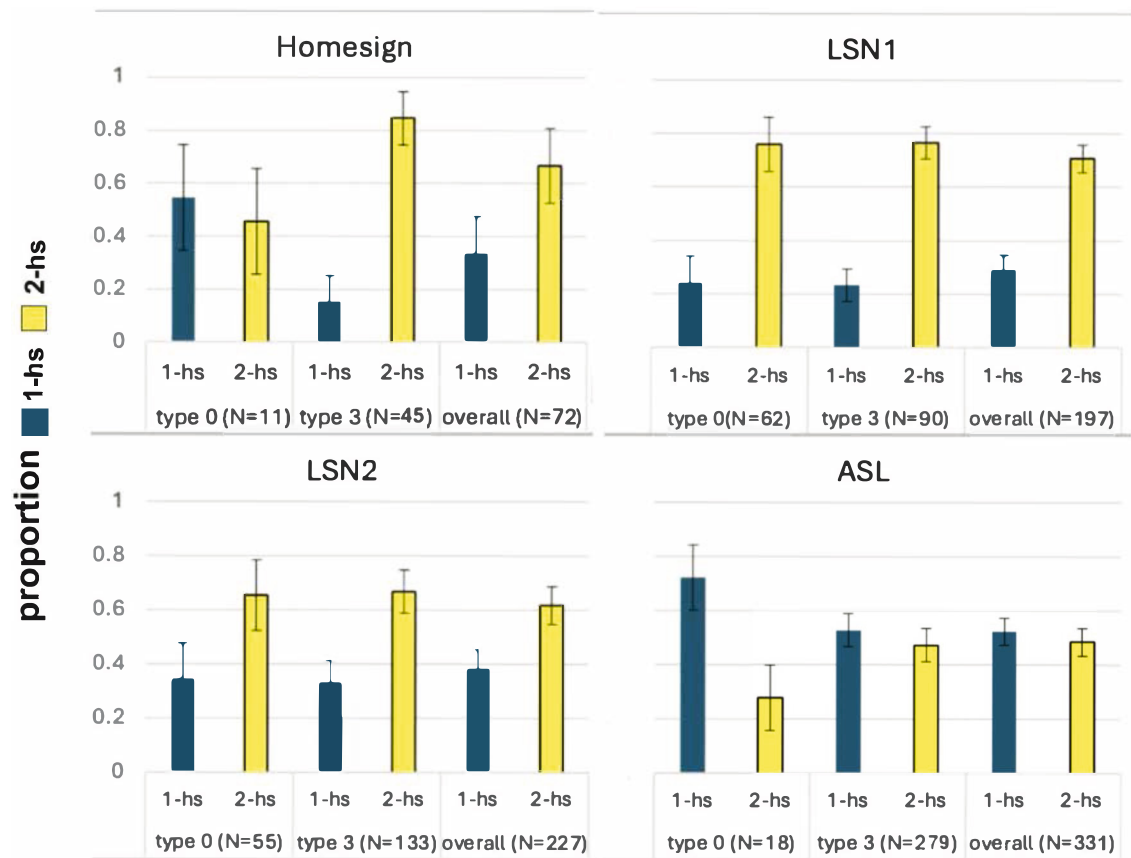

Figure 4: The proportion of 1-handshape (blue bars) and 2-handshape (yellow bars) across Nicaraguan groups and ASL in Type 0, Type 3, and overall.

These analyses show that when these handshapes are used as classifiers their distribution can be quite different than in the lexicon as a whole.

4.2 Semantic analysis of volitionality

The semantic analysis aimed to uncover patterns of form-meaning pairings in these two classifiers (CL-1 and CL-2) by analyzing the characteristics of the lexical entries in the collected dataset. The characteristics annotated include volitionality, handshape configurations, and hand-internal movement. As stated in Section 1, volitionality refers to the characteristic of a referent in a predicate indicating whether the referent intended to perform the action or, in the case of stative classifier predicates, intended to be in a particular state or location (Dowty 1991, Jackendoff 1992, Van Valin 2005). Based on an analysis of ASL and DTS (Engberg-Pedersen et al. 2025), our hypothesis is that we would find an association between the volitionality of the referent and (i) the choice of the classifier, or (ii) the use of hand-internal movement.

The annotated data were first exported from ELAN as a tab-delimited file (TDF). This TDF was subsequently converted into a comma-separated values (CSV) format using Visual Studio Code (Microsoft Corporation 2024) leveraging Python (Python Core Team 2019) for the conversion process. The resulting CSV file was then imported to R Studio (Posit Team 2024) for statistical processing and analysis using the R statistical programming language. This workflow ensured that the data were accurately formatted and prepared for comprehensive statistical analysis, facilitating the exploration of patterns and correlations within the dataset.

The R packages dplyr (Wickham et al. 2023), tidyverse (Wickham et al. 2019), esquisse (Meyer and Perrier 2024), and report (Makowski et al. 2023) were utilized for statistical processing and analysis. The Large Language Model ChatGPT (OpenAI 2024) was used to debug and simplify code throughout.

To quantify the statistical correlations between volitionality and handshape (i.e., selected finger group), volitionality and hand-internal movement, as well as between hand-internal movement and handshape, Fisher's exact tests were conducted. Fisher's exact test was chosen over the more common chi-squared test to accommodate the idiosyncratic nature of the smaller datasets available in an emerging language context such as LSN. These tests allowed us to examine the association between categorical variables and determine the strength and significance of these relationships.

By applying Fisher's exact tests, we were able to statistically validate whether the observed patterns in hand-internal movement and handshape configuration during classifier predicate production were influenced by volitionality. A classifier predicate with a volitional referent is one in which the referent has chosen their state, location, or the action they are performing. A classifier predicate with a non-volitional referent is one in which the referent has not chosen their state, location, or the action they are performing. The statistical processing of the data provided the following insights into the factors influencing classifier selection and sub-morphemic linguistic structures within and across Nicaraguan groups and ASL.

4.2.1 Increase in non-volitional classifier across Nicaraguan groups

As shown in Figure 5 (as compared with Figure 3), we see that while individual homesigners use both Cl-1 (1-handshape) and Cl-2 (2-handshape), they do so almost exclusively in volitional contexts. They did not incorporate non-volitional classifier predicates into their individual homesign systems at the frequency of later cohorts. While all groups used classifiers in non-volitional contexts, and all groups demonstrated hand-internal movement, non-volitional classifier predicates represented only 4.1% of the classifier predicates elicited by Canary Row retellings among individual homesigners. LSN1 more than doubled the individual homesigners' prevalence of non-volitional classifier predicates, with non-volitional classifier predicates representing 10.8% of classifier predicate productions. LSN2 nearly doubled LSN1's use of classifiers in non-volitional contexts yet again, with 18.4% of classifier predicates used non-volitionally. The ASL participants align much more closely with LSN2, with 15.8% of classifiers being produced in non-volitional contexts.

A pairwise *z*-test for proportion was conducted between the four groups. The statistical analysis reveals interesting patterns in the proportion of classifier predicates produced non-volitionally across groups. There is no statistically significant difference in the proportion of classifier predicates produced non-volitionally between individual homesigners and LSN1 (p = 0.285) despite a doubling in the absolute proportion.

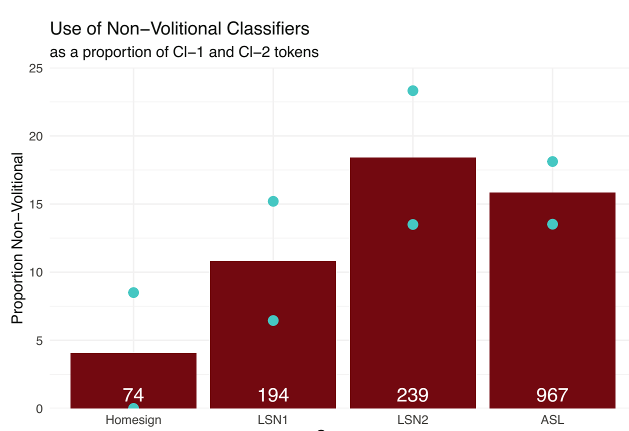

Figure 5: Proportion of tokens from each corpus which are non-volitional on a 0% through 25% scale. 95% confidence interval in teal; total tokens used to calculate percentage in white.

This indicates that while there is a noticeable increase in non-volitional classifier predicate use in LSN1 compared to homesigners, the difference is not substantial enough to reach statistical significance. Similarly, there is no statistically significant difference between LSN1 and LSN2 (p = 0.157), indicating a gradual, non-dramatic increase in the proportion of non-volitional classifier predicates as the language evolves.

However, the comparison between individual homesigners and LSN2 shows a statistically significant difference (*p = 0.028). This finding suggests that after only one generation of vertical transmission, the proportion of classifier predicates used non-volitionally becomes significantly different from the original input of the homesign systems. With this slow and steady increase in non-volitional use between generations, the accumulated difference by the second cohort of LSN signers marks a clear departure from the patterns seen in homesign systems, pointing to the influence of transmission and community on language creation.

4.2.2 LSN1 contextual preferences

LSN1 signers produced many more non-volitional classifier predicates than the individual homesigners (Figure 5). However, this increase in production is limited in its context. First, LSN1 non-volitional classifier predicates are almost entirely produced with the Cl-2 handshape, as seen in Figure 6a. Fisher's exact test bears out the statistical significance of the correlation at **p = 0.002508.

Second, looking exclusively at LSN1 we observed no hand-internal movement in non-volitional classifier predicates, as seen in Figure 6b. A Fisher's exact test demonstrates the significance of this correlation at ***p = 0.0008418.

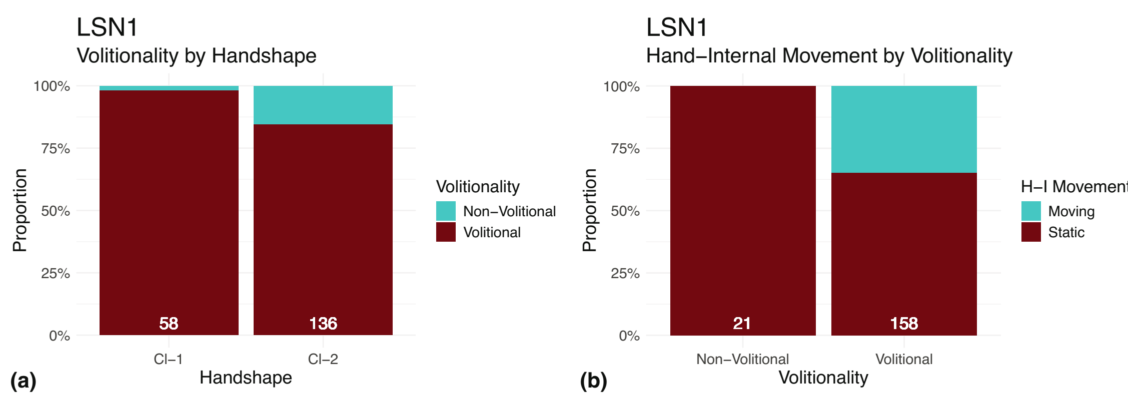

Figure 6: (a) Percent of Cl-1 and Cl-2 signs observed to be volitional or non-volitional (by fill color) in the LSN1 dataset. Total annotated tokens in white. (b) Percent of volitional and non-volitional classifier predicates observed to contain hand-internal movement (by fill color) in the LSN1 dataset. Total annotated tokens in white.

4.2.3 LSN2 expands the contexts for using Cl-1 and Cl-2

The increase in production of non-volitional Cl-1 and Cl-2 classifiers was also observed in LSN2; however, the specificity of the context required for a classifier predicate to be used non-volitionally was not.

As shown in Figure 5, LSN2 demonstrates an increased use of non-volitional classifier predicates over both individual homesigners and LSN1. Moreover, LSN2 produces both Cl-1 and Cl-2 in non-volitional contexts, not Cl-2 exclusively as in LSN1 (Figure 7a). In addition, hand-internal movement is used in both volitional and non-volitional contexts (Figure 7b). Fisher's exact tests show no statistically significant correlation between volitionality and handshape or volitionality and hand-internal movement in LSN2, at p = 0.3637 and p = 0.1196, respectively.

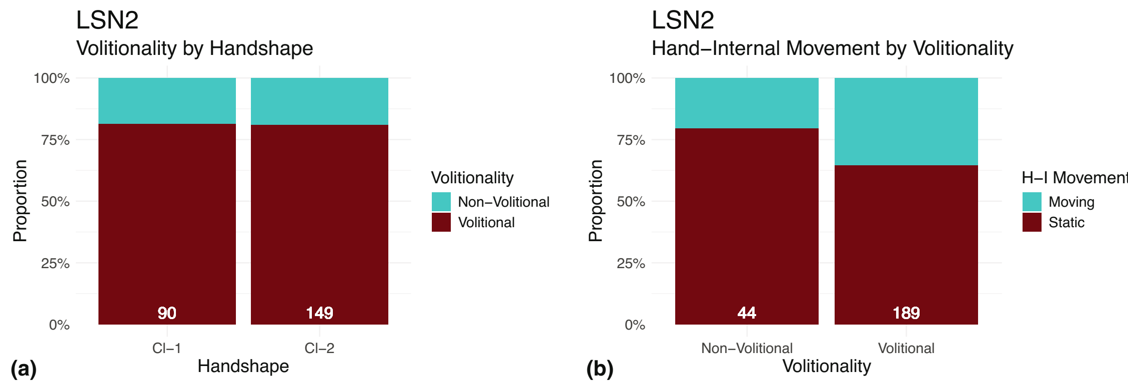

Figure 7: (a) Proportion of volitional and non-volitional classifier predicates (by fill) observed in Cl-1 and Cl-2 in LSN2. (b) Hand-internal movement (by fill color) produced in non-volitional and volitional contexts in LSN2. Total annotated tokens in white.

4.2.4 Movement as the domain of Cl-2

Despite these changes in usage patterns among LSN2 signers: (i) non-volitional classifier predicates being produced using Cl-1, and (ii) hand-internal movement being used in non-volitional contexts, no significant increase in hand-internal movement, as a proportion of Cl-1 classifier predicate productions, was observed (Figure 8a and b).

The lack of an increase between LSN1 and LSN2 in hand-internal movement in the Cl-1 handshape, despite the increasing use of hand-internal movement non-volitionally and increasing non-volitional uses of the Cl-1, raises an important question: Does LSN2 still make a volitional/non-volitional distinction?

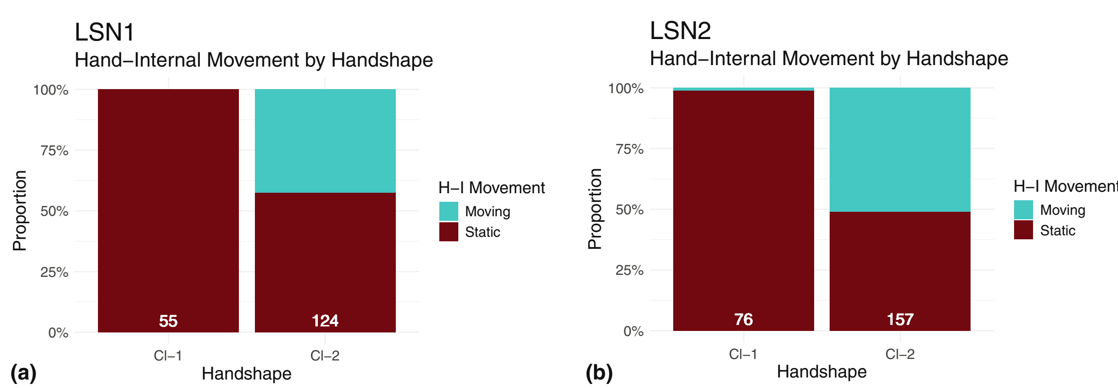

Figure 8: (a) Proportion of classifier predicates which contained hand-internal movement (by fill color) in LSN1 by handshape. (b) Proportion of classifier predicates which contained hand-internal movement (by fill color) in LSN2 by handshape. Total annotated tokens in white.

4.2.5 Hand-internal movement in non-volitional contexts

The infiltration of hand-internal movement in non-volitional classifier predicates that occurs in LSN2 occurs exclusively in the Cl-2 handshape. To account for this phenomenon, we explored two possible explanations.

The first explanation might be an increase in the variety of Cl-2 forms acceptable in non-volitional contexts. Variants of the Cl-2 handshape, novel to LSN, being added to the LSN2 classifier inventory could account for this increase in hand-internal movement in the Cl-2 handshape as a whole by providing additional opportunities for non-volitional use of hand-internal movement. However, the only addition Cl-2 variant observed in LSN2 was a form of the stacked Cl-2 handshape produced with hand-internal movement, which appeared only once in our dataset (for 'falling'). The rarity of this variant makes it a poor explanation for the increasing flexibility in Cl-2 usage observed in LSN2.

The second possible explanation considered was an increase in hand-internal movement in the already available phonological forms. Specifically, it is possible that LSN2 signers were expanding the use of hand-internal movement in the currently available variants of the Cl-2 handshape. The least marked version of the Cl-2 handshape demonstrating hand-internal movement is the inverted form with hand-internal movement at the MCP joints, iconically representing the legs of an upright human or anthropomorphic referent walking (i.e., the 2m (Cl-2 moving) handshape) (Eccarius and Brentari 2007, Hara 2003). In order to expand the use of hand-internal movement, LSN2 signers would have to increase hand-internal movement in variants outside of this 2m form.

To investigate this, a two-proportion *Z*-test was conducted to determine whether there was a statistically significant difference in the proportions of Cl-2 handshape classifiers performed in their bent and stacked forms between LSN1 and LSN2.

Results showed a statistically significant increase in the proportion of moving Cl-2 classifiers outside of the 2m variant $^*p = 0.0430672$. LSN1 signers produced 8.96% their Cl-2 classifiers using non-2m variants, while LSN2 nearly doubled that percentage, using 15.53% non-2m variants of Cl-2 classifiers (Figure 9). These proportions represent a near doubling in absolute count as well (Table 3).

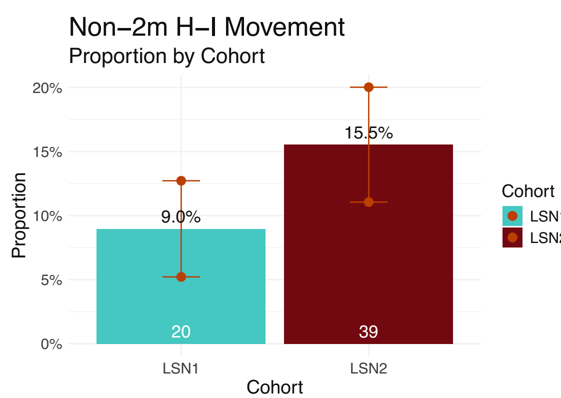

Figure 9: Proportion of non-2m hand-internal movement by cohort (by fill). 95% confidence interval in orange.

Table 3: Proportions of non-2m classifiers showing hand-internal movement

Cohort	Total tokens	Non-2m	Proportion	Percentage
LSN1	223	20	0.089	8.97
LSN2	251	39	0.1553785	15.53

4.2.6 Diachronic semantic analysis

The analysis of the semantic conditioning of handshape reveals multiple diachronic developments from homesigners through LSN2. Classifier use is sparse among individual homesigners, becoming more common only after signers are brought together, facilitating horizontal transmission. This horizontal transmission conditioned the increased use of both the Cl-1 and Cl-2 handshapes in LSN1. In the early stages of classifier introduction, strict contextual preferences emerge, as seen in LSN1. These preferences included a restriction on using Cl-1 in non-volitional contexts and a contextual preference against hand-internal movement in non-volitional contexts.

As LSN's classifier system underwent vertical transmission, greater flexibility in classifier use developed. In LSN2, this manifests as a relaxation of the contextual preferences against using Cl-1 in non-volitional contexts and an increased acceptance of hand-internal movement in non-volitional contexts.

However, this flexibility did not extend to accepting hand-internal movement in the Cl-1 handshape itself. Notably, LSN2 signers increased the use of hand-internal movement in non-2m handshapes and dropped the prohibition on hand-internal movement in non-volitional contexts. These findings highlight the complex interplay between horizontal and vertical transmission processes in shaping the evolution of classifier systems.

5 Discussion

Our analyses reveal important generalizations about the nature of the distribution of Cl-1 and Cl-2 classifier predicates in relation to animate referents in a young sign language, such as LSN.

With regard to phonology, we see patterns in the distribution of 1-handshape and 2-handshape that differ from predictions based on previous work on sign languages for the lexicon as a whole; namely, we find that the simpler structure (the 1-handshape) is not more frequent in the contexts addressed here. It is clear from these results that the phonological distribution of classifier selection is not based primarily on the complexity of the handshape nor on the form as a whole. But, in our observations of the Nicaraguan groups, we see that the nature of an emerging phonological system has an impact on the forms that will appear most frequently. First, we see that LSN1 signers are the only group with a significant preference for the 2-handshape. Second, we see that LSN1 signers use 1-handed classifier predicates (Type 0 signs) as a higher proportion of their classifier predicate constructions than the other groups, even individual homesigners (Table 2). Third, we observed that individual homesigners are more likely to use marked handshapes on the non-dominant hand than the other two Nicaraguan groups or ASL (Section 4.1 and Brentari et al. (2024), which analyzed the handshape inventory Nicaraguan homesigners and LSN signers). These generalizations suggest that LSN1 is in the process of re-organizing the phonological system in important ways. The phonological analysis indicates that the constraints on 1-handshape and 2-handshape as they are used in Cl-1 and Cl-2 are not based on exclusively phonetic or articulatory considerations. If articulatory constraints were the only factor, we would expect to see patterns that were more similar across populations. The distribution of 1-handshape and 2-handshape interacts with the phonological system as a whole as well as with iconicity and morphological categories, such as those analyzed in Section 4.2.

With regard to semantics, we find that volitionality plays a significant role in the use of classifiers within the sign languages studied in the current analysis. Classifiers are more frequent in volitional than non-volitional events. The data clearly indicate that when a referent's action is volitional – that is, performed with intention – signers are more likely to produce classifier predicates. This patterning suggests that volitionality acts as one semantic factor mediating classifier use. The significance of volitionality in classifier predicate productions hints at the importance of more abstract factors in the processes underpinning sign language grammar and production.

Additionally, we observed diachronic changes in the precise nature of these strategies. Individual homesigners use Cl-1 and Cl-2 primarily to communicate volitional actions (Figure 5). This tendency to avoid classifier constructions in non-volitional contexts highlights a unique linguistic behavior that differentiates the Nicaraguan individual homesign systems from later Nicaraguan cohorts. In future work, it would be interesting to know exactly what individual homesigners are doing when they are not using Cl-1 and Cl-2. Are they possibly using constructed action, lexical signs, alternate classifier handshapes, or something else? In Israeli Sign Language (Stamp, in preparation), also a young sign language, constructed action is more frequent in older signers and classifier use is more frequent in younger signers.

In our dataset, both LSN1 and LSN2 signers expanded the functional scope of Cl-1 and Cl-2 beyond what was observed in individual homesigners, with LSN1 increasing the use of Cl-1 and Cl-2 in non-volitional contexts beyond that of the individual homesigners, and LSN2 increasing the use of these two classifiers in non-volitional classifier contexts beyond that of LSN1. Interestingly, LSN1 signers appear to focus their restructuring efforts predominantly on Cl-2 forms. This is evident as nearly all non-volitional forms in LSN1 are represented by Cl-2 classifiers, and the association between hand-internal movement and volitionality is exclusively observed within Cl-2 forms as well (Figure 6b).

As LSN is transmitted across cohorts, the use of classifiers in non-volitional contexts becomes more common. LSN1 signers showed a strong preference for the CL-2 handshape in non-volitional contexts and held to strict contextual preferences on hand-internal movement in Cl-2 as well, confining it almost entirely to volitional actions. This may seem less coherent as a system, with Cl-2 being the domain of both non-volitional events as well as the exclusive home of hand-internal movement, but as the ultimate goal of any sign language system is communication, we should not be surprised that signers are using the tools at their disposal to perform the grammatical tasks necessary to communicate effectively. The strong statistical correlations linking handshape and hand-internal movement with volitionality, *p*-values of **0.002 and ***0.0008, respectively, compared with the individual homesigners at 0.79 and 0.32 indicate a re-structuring of the system, but this restructuring is happening exclusively with Cl-2 classifiers.

In the progression from LSN1 to LSN2, there are additional noteworthy changes in the use of classifiers for volitional and non-volitional events. LSN2 signers increase the proportion of non-volitional use to over 18%, and they use both Cl-1 and Cl-2 classifiers in volitional and non-volitional contexts.

Finally, the link between hand-internal movement and handshape is evident in both LSN1 and LSN2. This correlation suggests that the physical characteristics of the sign, such as hand-internal movement and handshape, are closely intertwined and collectively contribute to the semantic interpretation of the classifier. It may be that LSN signers are concentrating all of their re-structuring on Cl-2 for these reasons. LSN2 signers extended the use of hand-internal movement in non-volitional contexts and began to use it in a greater proportion of marked Cl-2 variants. The pattern observed in LSN2 aligns with that found in ASL, which also does not link volitionality directly with the selected finger group (Cl-1 vs Cl-2) at a statistically significant level. Although this association is not currently found in LSN2 signers, they are likely to be moving toward a more differentiated system (Engberg-Pedersen et al. 2025).

5.1 For future investigation

This study has raised several questions that warrant further investigation to deepen our understanding of classifier predicate usage in LSN and related developing signing systems.

First, an exploration of which strategies homesigners are employing in contexts in which LSN1 or LSN2 signers would typically produce a classifier predicate would be helpful in outlining the development of classifier systems as a whole.

Second, further research is needed to examine how LSN2 signers are currently using the Cl-1 handshape in non-volitional contexts. With hand-internal movement restricted to the Cl-2 handshape, a more detailed analysis of which other contexts and phonological factors might condition the use of the Cl-1 handshape non-volitionally is called for.

Third, future studies should extend the scope of investigation to LSN3 to determine whether the trends observed in LSN2 continue in the next generational iteration of the language. Analyzing LSN3 could help clarify whether the observed changes are part of a broader trajectory of language evolution or specific to LSN2.

6 Conclusion

Our key findings concern both phonology and semantics of sign language grammar, broadly construed, as well as the specific role that the distribution of Cl-1 and Cl-2 play in the classifier systems of a young sign language. Since these two classifiers refer to *person* in some way, we ask what might be motivating their distribution other than style or the iconic properties of form. We find that an emerging phonological system, as seen in the Nicaraguan groups' data analyzed here, interacts with the production of predicates, especially as they relate to

1-handed vs 2-handed forms and the variation in handshapes that can appear in complex 2-handed classifiers. More importantly, we find that the whole handshape (all subtypes CL-1s and all Cl-2s) do not behave in identical ways as unanalyzable wholes, and there is a strong correlation between hand-internal movement and volitionality in some groups. This supports prior work showing that properties of handshape can be decomposed and singled out for specific grammatical roles and functions in classifier predicates.

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Conflict of interest: The authors state no conflict of interest.

Data availability statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

References

Battison, Robbin. 1978. *Lexical Borrowing in American Sign Language*. Silver Spring, MD: Linstok Press. Reprinted. 2003, Burtonsville, MD: Sign Media, Inc

Benedicto, Elena and Diane Brentari. 2004. "Where did all the Arguments Go?: Argument-Changing Properties of Classifiers in ASL." *Natural Language and Linguistic Theory* 22 (4): 743–810. doi: 10.1007/s11049-003-4698-2.

Bosworth, Rain G. and Karen Emmorey. 2010. "Effects of Iconicity and Semantic Relatedness on Lexical Access in American Sign Language." *Journal of Experimental Psychology: Learning, Memory, and Cognition* 36 (6): 1573–81. doi: 10.1037/a0020934.

Boyes Braem, Penny Kaye. 1981. "Features of the Handshape in American Sign Language." PhD diss., University of California, Berkeley.

Brentari, Diane. 1998. *A Prosodic Model of Sign Language Phonology*. Cambridge, MA: MIT Press. doi: 10.7551/mitpress/5644.001.0001.

Brentari, Diane. 2012. "Phonology." In *Sign Language: An International Handbook*, edited by R. Pfau, M. Steinbach, and B. Woll, 21–54. Walter de Gruyter.

Brentari, Diane. 2019. *Sign Language Phonology*, 1st ed., Cambridge, UK: Cambridge University Press. doi: 10.1017/9781316286401.

Brentari, Diane, Susan Goldin-Meadow, Laura Horton, Ann Senghas, and Marie Coppola. 2024. "The organization of verb meaning in Lengua de Señas Nicaragüense (LSN): Sequential or simultaneous structures?," *Glossa: A Journal of General Linguistics* 9 (1). doi: doi: 10.16995/glossa.10342.

Brentari, Diane, Marie Coppola, Pyeong-Whan Cho, and Ann Senghas. 2017. "Handshape Complexity as a Precursor to Phonology: Variation, Emergence, and Acquisition." *Language Acquisition* 24 (4): 283–306. doi: 10.1080/10489223.2016.1187614.

Brentari, Diane, Marie Coppola, Laura Mazzoni, and Susan Goldin-Meadow. 2012. "When does a System become Phonological? Handshape Production in Gesturers, Signers, and Homesigners." *Natural Language & Linguistic Theory* 30 (1): 1–31. doi: 10.1007/s11049-011-9145-1.

Brentari, Diane, Alessio D. Renzo, Jonathan Keane, and Virginia Volterra. 2015. “Cognitive, Cultural, and Linguistic Sources of a Handshape Distinction Expressing Agentivity.” *Topics in Cognitive Science* 7 (1): 95–123. doi: 10.1111/tops.12123.

Caselli, Naomi K., Karen Emmorey, and Ariel M. Cohen-Goldberg. 2021. “The Signed Mental Lexicon: Effects of Phonological Neighborhood Density, Iconicity, and Childhood Language Experience.” *Journal of Memory and Language* 121: 104282. doi: 10.1016/j.jml.2021.104282.

Caselli, Naomi K. and Jennie E. Pyers. 2017. “The Road to Language Learning Is Not Entirely Iconic: Iconicity, Neighborhood Density, and Frequency Facilitate Acquisition of Sign Language.” *Psychological Science* 28 (7): 979–87. doi: 10.1177/0956797617700498.

Coppola, Marie. 2021. “Sociolinguistic Sketch: Nicaraguan Sign Language and Homesign Systems in Nicaragua.” *Emerging Sign Languages of the Americas*, edited by Olivier Le Guen, Josefina Safar, and Marie Coppola, 439–50. Berlin, Boston: De Gruyter Mouton. doi: 10.1515/9781501504884-015.

Coppola, Marie and Diane Brentari. 2014. “From Iconic Handshapes to Grammatical Contrasts: Longitudinal Evidence from a Child Homesigner.” *Frontiers in Psychology: Language Sciences*. doi: 10.3389/fpsyg.2014.00830.

Coppola, Marie and Elissa L. Newport. 2005. “Grammatical Subjects in Home Sign: Abstract Linguistic Structure in Adult Primary Gesture Systems without Linguistic Input.” *Proceedings of the National Academy of Sciences* 102 (52): 19249–53. doi: 10.1073/pnas.0509306102.

Coppola, Marie and Elissa L. Newport. 2006. “Grammatical subjects in home sign: Abstract linguistic structure in adult primary gesture systems without linguistic input.” *Proceedings of the National Academy of Sciences of the United States of America* 102 (52): 19249–53. doi: 10.1073/pnas.0509306102.

Cormier, Kearsy, David Quinto-Pozos, Zed Sevcikova, and Adam Schembri. 2012. “Lexicalisation and De-Lexicalisation Processes in Sign Languages: Comparing Depicting Constructions and Viewpoint Gestures.” *Language & Communication* 32 (4): 329–48. doi: 10.1016/j.langcom.2012.09.004.

Crasborn, Onno and Han Sloetjes. 2008. “Enhanced ELAN Functionality for Sign Language Corpora.” *International Conference on Language Resources and Evaluation*.

Dowty, David. 1991. “Thematic Proto-Roles and Argument Selection.” *Language* 67 (3): 547–619. doi: 10.2307/415037.

Eccarius, Petra Nichole. 2008. “A Constraint-based Account of Handshape Contrast in Sign Languages.” PhD diss., Purdue University.

Eccarius, Petra and Diane Brentari. 2007. “Symmetry and Dominance: A Cross-Linguistic Study of Signs and Classifier Constructions.” *Lingua* 117(7): 1169–201.

Edward, Mary. 2021. “Iconicity as a pervasive force in language: Evidence from Ghanaian Sign Language and Adamorobe Sign Language.” PhD diss., University of Brighton.

Emmorey, Karen. 2003. *Perspectives on Classifier Constructions in Sign Languages*. (1st ed.). New York, NY: Psychology Press. doi: 10.4324/9781410607447.

Emmorey, Karen, Hanna Damasio, Stephen McCullough, Thomas Grabowski, Laura L. B. Ponto, Richard D. Hichwa, and Ursula Bellugi. 2003. “Neural Systems Underlying Spatial Language in American Sign Language.” *NeuroImage* 17 (2): 812–24. doi: 10.1006/nimg.2002.1187.

Emmorey, Karen and Melissa Herzig. 2003. “Categorical Versus Gradient Properties of Classifier Constructions in ASL.” In *Perspectives on Classifier Constructions in Sign Languages*, edited by K. Emmorey, 221–46. Lawrence Erlbaum Associates.

Engberg-Pedersen, Elisabeth. 1993. “Space in Danish Sign Language. The Semantics and Morphosyntax of the Use of Space in a Visual Language.” In *International Studies on Sign Language Research and Communication of the Deaf*, Vol. 19. Hamburg: Signum Verlag. *Nordic Journal of Linguistics* 18 (1): 67–74. doi: 10.1017/S0332586500003115.

Engberg-Pedersen, Elisabeth, Diane Brentari, and Jeffery Davis. 2025. “Formal and Functional Factors in classifier choice: Evidence from American Sign Language (ASL) and Danish Sign Language (DTS)”. *Open Linguistics*. 11 (1): 20250043. doi: 10.1515/opli-2025-0043.

Freleng, Friz. 1949. *Canary Row*. Warner Bros. Cartoons.

Gappmayr, Paris, Amy M. Lieberman, Jennie Pyers, and Naomi K. Caselli. 2022. “Do Parents Modify Child-Directed Signing to Emphasize Iconicity?” *Frontiers in Psychology* 13: 920729. doi: 10.3389/fpsyg.2022.920729.

Goico, Sara A. and Laura Horton. 2023. “Homesign: Contested Issues.” *Annual Review of Linguistics* 9 (1): 377–98. doi: 10.1146/annurev-linguistics-030521-060001.

Gökgöz, Kadir. 2024. “Verbal Classifiers from a Crosslinguistic and Cross-Modal Point of View.” *Language* 100 (2): 179–217. doi: 10.1353/lan.2024.a929735.

Goldin-Meadow, Susan. 2003. *The Resilience of Language: What Gesture Creation in Deaf Children can tell us about how all Children Learn Language*. New York: Psychology Press. doi: 10.4324/9780203943267.

Goldin-Meadow, Susan, Diane Brentari, Marie Coppola, Laura Horton, and Ann Senghas. 2015. “Watching Language Grow in the Manual Modality: Nominals, Predicates, and Handshapes.” *Cognition* 136: 381–95. doi: 10.1016/j.cognition.2014.11.029.

Hara, Daisuke. 2003. “A Complexity-based Approach to the Syllable Formation in Sign Language.” PhD diss., University of Chicago.

Hulst, Harry van der. 1996. “On the other Hand.” *Lingua* 98 (1–3): 121–43. doi: 10.1016/0024-3841(95)00035-6.

Jackendoff, Ray S. 1992. *Semantic Structures*. Cambridge: The MIT Press.

Kegl, Judy and Gail Iwata. 1989. “Lenguaje de Signos Nicaragüense: A pidgin sheds light on the "creole?" ASL.” In *Proceedings of the Fourth Meeting of the Pacific Linguistics Conference*, edited by R. Carlson, S. DeLancey, S. Gildea, D. Payne, & A. Saxena, 266–94. Department of Linguistics, University of Oregon, Eugene, OR.

Kegl, Judy A. 1999. *Creation through contact : Sign language emergence and sign language change in Nicaragua*.

Kimmelman, V., Khristoforova, E., Loos, C., Börstell, C., Simper-Allen, P., & Zorzi, G. 2025. *Classifier Choice Annotation Guidelines*. doi: 10.17605/OSF.IO/M7KT9.

Labov, William. 1994. “Principles of Linguistic Change. Volume I: Internal Factors. (Language in Society 20).” *Journal of Linguistics* 31 (2): 435–9. doi: 10.1017/S0022226700015693.

Ladefoged, Peter and Ian Maddieson. 1996. *The Sounds of the World's Languages*. Blackwell.

Levshina, Natalia and Steven Moran. 2021. “Efficiency in Human Languages: Corpus Evidence for Universal Principles.” *Linguistics Vanguard* 7 (s3): 20200081. doi: 10.1515/lingvan-2020-0081.

Liddell, Scott K. and Robert E. Johnson. 1989. “American Sign Language: The Phonological Base.” *Sign Language Studies* 64 (1): 195–277. doi: 10.1353/sls.1989.0027.

Makowski, Dominique, Daniel Lüdecke, Indrajeet Patil, Rémi Thériault, Mattan S. Ben-Shachar, and Brenton M. Wiernik. 2023. *Automated Results Reporting as a Practical Tool to Improve Reproducibility and Methodological Best Practices Adoption*. CRAN. https://easystats.github.io/report/.

Mandel, Mark Alan. 1981. “Phonotactics and Morphophonology in American Sign Language.” PhD diss., University of California, Berkeley.

Meyer, Fanny and Victor Perrier. 2024. *esquisse: Explore and Visualize Your Data Interactively*. CRAN. doi: 10.32614/CRAN.package.esquisse.

Microsoft Corporation. 2024. *Microsoft Visual Studio*. Version 1.92. Microsoft. https://visualstudio.microsoft.com/.

Nyst, Victoria. 2010. “Sign Languages in West Africa.” In *Sign Languages*, edited by Diane Brentari, 405–32. Cambridge Language Surveys. Cambridge: Cambridge University Press.

Nyst, Victoria, Marta Morgado, Timothy Mac Hadjah, Marco Nyarko, Mariana Martins, Lisa Van Der Mark, Evans Burichani, Tano Angoua, Moustapha Magassouba, Dieydi Sylla, Kidane Admasu, and Anique Schüller. 2022. “Object and Handling Handshapes in 11 Sign Languages: Towards a Typology of the Iconic Use of the Hands.” *Linguistic Typology* 26 (3): 573–604. doi: 10.1515/lingty-2021-0026.

OpenAI. 2024. *ChatGPT*. Version 4.o. OpenAI. https://openai.com/chatgpt.

Ortega, Gerardo and Gary Morgan. 2015. “Phonological Development in Hearing Learners of a Sign Language: The Influence of Phonological Parameters, Sign Complexity, and Iconicity.” *Language Learning* 65 (3): 660–88. doi: 10.1111/lang.12123.

Ortega, Gerardo, Beyza Sümer, and Asli Özyürek. 2014. “Type of Iconicity Matters: Bias for Action-based Signs in Sign Language Acquisition.” In *Proceedings of the 36th Annual Meeting of the Cognitive Science Society (CogSci 2014)*, edited by Paul Bello, Marcello Guarini, Marjorie McShane, and Brian Scassellati, 1114–9. Austin, TX: Cognitive Science Society.

Perniss, Pamela M. and Aslı Özyürek. 2008. “Representations of Action, Motion and Location in Sign Space: A Comparison of German (DGS) and Turkish (TID) Sign Language Narratives.” In *Signs of the time: Selected papers from TISLR 8*, edited by J. Quer, 353–76. Seedorf: Signum Press.

Polich, Laura. 2005. “Chapter 11. The Diagnosis of Deafness in Nicaragua.” In *Diagnosis as Cultural Practice*, edited by Judith Felson Duchan and Dana Kovarsky, 223–40. New York: Mouton de Gruyter. doi: 10.1515/9783110199802.223.

Posit Team. 2024. *RStudio: Integrated Development Environment for R*. Version 2024.04.2 + 764. Posit Software, PBC. http://www.posit.co/.

Power, Justin M. 2022. “Historical Linguistics of Sign Languages: Progress and Problems.” *Frontiers in Psychology* 13: 818753. doi: 10.3389/fpsyg.2022.818753.

Power, Justin M. and Richard Meier. 2023. “Demographics in the Formation of Language Communities and in the Emergence of Languages: The Early Years of ASL in New England.” *Language* 99 (2): 275–316. doi: 10.1353/lan.2023.a900088.

Python Core Team. 2019. *Python: A Dynamic, Open Source Programming Language*. Version 3.12. Python Software Foundation. https://www.python.org/.

Rozelle, Lorna. 2003. “The Structure of Sign Language Lexicons: Inventory and Distribution of Handshape and Location.” PhD diss., University of Washington.

Senghas, Ann. 1995. “Children’s Contribution to the Birth of Nicaraguan Sign Language.” PhD diss., Massachusetts Institute of Technology.

Senghas, Ann. 2003. “Intergenerational Influence and Ontogenetic Development in the Emergence of Spatial Grammar in Nicaraguan Sign Language.” *Cognitive Development* 18 (4): 511–31. doi: 10.1016/j.cogdev.2003.09.006.

Senghas, Ann and Marie Coppola. 2001. “Children Creating Language: How Nicaraguan Sign Language Acquired a Spatial Grammar.” *Psychological Science* 12 (4): 323–8. doi: 10.1111/1467-9280.00359.

Senghas, Ann, Sotaro Kita, and Asli Özyürek. 2004. “Children Creating Core Properties of Language: Evidence from an Emerging Sign Language in Nicaragua.” *Science* 305 (5691): 1779–82. doi: 10.1126/science.1100199.

Slonimska, Anita, Asli Özyürek, and Olga Capirci. 2022. “Simultaneity as an Emergent Property of Efficient Communication in Language: A Comparison of Silent Gesture and Sign Language.” *Cognitive Science* 46 (5): e13133. doi: 10.1111/cogs.13133.

Supalla, Ted. 1982. “Structure and Acquisition of Verbs of Motion and Location in American Sign Language.” PhD diss., University of California San Diego.

Supalla, Ted. 1986. “The Classifier System in American Sign Language.” In *Typological Studies in Language* (Vol. 7). edited by Colette G. Craig, 181–214. Amsterdam: John Benjamins Publishing Company. doi: 10.1075/tsl.7.13sup.

Tang, Gladys W. L. and Jia Li. 2018. “Acquisition of Classifier Constructions in HKSL by Bimodal Bilingual Deaf Children of Hearing Parents.” *Frontiers in Psychology* 9, Article 1148. doi: 10.3389/fpsyg.2018.01148.

Taub, Sarah F. 2001. *Language from the Body: Iconicity and Metaphor in American Sign Language*. Cambridge, UK: Cambridge University Press doi: 10.1017/CBO9780511509629.

Van Valin, Jr., Robert D. 2005. *Exploring the Syntax-Semantics Interface*. 1st ed., Cambridge, UK: Cambridge University Press. doi: 10.1017/CBO9780511610578.

Wickham, Hadley, Mara Averick, Jennifer Bryan, Winston Chang, Lucy D'Agostino McGowan, Romain François, Garrett Grolemund, Alex Hayes, Lionel Henry, Jim Hester, Max Kuhn, Thomas Lin Pedersen, Evan Miller, Stephan Milton Bache, Kirill Müller, Jeroen Ooms, David Robinson, Dana Paige Seidel, Vitalie Spinu, Hiroaki Yutani, et al. 2019. "Welcome to the Tidyverse." *Journal of Open Source Software* 4 (43): 1686. doi: 10.21105/joss.01686.

Wickham, Hadley, Romain François, Lionel Henry, Kirill Müller, and Davis Vaughan. 2023. "dplyr: A Grammar of Data Manipulation." CRAN. https://CRAN.R-project.org/package=dplyr.

Zwitserlood, Inge. 2012. "8. Classifiers." In *Sign Language: An International Handbook*, edited by Roland Pfau, Markus Steinbach, and Bencie Woll, 158–86. Boston: De Gruyter Mouton. doi: 10.1515/9783110261325.158.