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Handshape Complexity as a Precursor to Phonology: Variation, Emergence, and Acquisition

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\textbf{ABSTRACT}

In this article two dimensions of handshape complexity are analyzed as potential building blocks of phonological contrast—joint complexity and finger group complexity. We ask whether sign language patterns are elaborations of those seen in the gestures produced by hearing people without speech (pantomime) or a more radical reorganization of them. Data from adults and children are analyzed to address issues of cross-linguistic variation, emergence, and acquisition. Study 1 addresses these issues in adult signers and gesturers from the United States, Italy, China, and Nicaragua. Study 2 addresses these issues in child and adult groups (signers and gesturers) from the United States, Italy, and Nicaragua. We argue that handshape undergoes a fairly radical reorganization, including loss and reorganization of iconicity and feature redistribution, as phonologization takes place in both of these dimensions. Moreover, while the patterns investigated here are not evidence of duality of patterning, we conclude that they are indeed phonological and that they appear earlier than related morphosyntactic patterns that use the same types of handshape.

\textbf{ARTICLE HISTORY}

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1. Introduction

Starting with the work of Stokoe (1960) over fifty years ago, linguists have shown phonological structure in sign languages to be similar in many ways to spoken language phonology. In sign language phonology, the basic manual parameters are the handshapes, locations, and movements of signs. With respect to the features of these parameters, sign languages have minimal pairs, phonological production rules, and hierarchical feature structure autonomous from other components of the grammar, like that of their spoken language counterparts (for recent overviews see Brentari 2011a, 2011b, 2012; and Sandler 2011, 2012). Studies of acquisition reveal that the acquisition of phonological structure proceeds along a time course similar to spoken languages with comparable complexity in morphology and morphophonology (Boyes Braem 1981; Marentette & Mayberry 2000; Morgan, Barrett-Jones & Stoneham 2007; Volterra 1987; Tang et al. 2008; Meier et al. 2008; Chen-Pichler 2012).

In this article we examine how one parameter in a sign language—handshape—might vary cross-linguistically: how it emerges in historical time, and how it might be guided, in part, by mechanisms of language acquisition. As a language is passed from one generation to the next, child learners can have an influence on its structure, ultimately acquiring a language that differs from the one modeled by the previous generation (Sankoff & Labelge 1973). We are fortunate to have the opportunity to observe such developments in a very young language, Nicaraguan Sign Language (NSL), which has emerged over the past four decades. By comparing the signs of Nicaraguan adults and children with the signs of more well-established sign languages, and by comparing these signs, in turn, with the
gestures produced by hearing members of the local spoken language communities, we can capture the nature of the earliest elements of sign language phonology. We cannot observe how the emergence and acquisition of phonology relate to one another in spoken languages because the relevant development took place millennia in the past, but we can do so in the manual modality by observing presently emerging sign languages such as NSL. We would expect that in the earliest years of the emergence of a new language, the impact of the acquisition process would be most evident, as aspects of the grammar first take on a systematic structure (Senghas 1995; Senghas & Coppola 2001).

Handshape is one of the sublexical phonological units of sign languages and can be thought of as a natural class, the way that obstruents (stops and fricatives) form a natural class in spoken languages. Consider that obstruents have a particular time course in first-language acquisition. They appear as single consonants before they appear in clusters, in word-initial position before word-final position, and stops are mastered before fricatives (Vihman, 1996). Moreover, these sounds are mastered later where they interact with morphology than where they are a part of simple stems (see MacWhinney 1978 for English, and Ravid & Schiff 2009 for Hebrew). This kind of interaction of phonology and morphology, with respect to the natural classes of handshapes, is the focus of this article. The interaction is examined in the contexts of sign language acquisition and emergence.

We start from the assumption that sign language has both gestural and linguistic elements, and by comparing signed and gestured responses, we can distinguish the parts of the signed system that are due to linguistic rather than to the gestural properties of responses. Patterns that are shared by signers and gesturers are considered to be gestural—i.e., not the forms alone but rather the distribution of those forms in the system. In the following two studies the complexity of two types of handshapes that are ubiquitous and meaningful in both sign and gesture are examined: Object handshapes, those in which the hand represents properties of objects, such as size, shape, and class, and in so doing use “hand-as-object” iconicity, and Handling handshapes, those in which the hand represents how objects are manually manipulated, and which use “hand-as-hand” iconicity (see Figure 1 for examples).

Handshape was chosen as a focus of our studies because handshape has been shown to exhibit notable differences between gesture and sign, particularly in adults, and much more so than movement and location, the two other manual sign language parameters (Goldin-Meadow, McNeill & Singleton 1996; Schembri, Jones & Burnham 2005).

The first study replicates and expands on previous work on this topic with adults from Italy and the United States (Brentari et al. 2012). We compare the handshape complexity of deaf adult signers to that of hearing adults gesturing without speaking, across four countries: Italy, the United States, Nicaragua, and China. Complementing this prior work, we analyze both finger complexity and joint complexity, a second dimension of handshape not previously considered. Three of the four sign languages are well established—American Sign Language (ASL), Italian Sign Language (LIS), and Chinese Sign Language (CSL)—dating back at least 100 years (Fischer & Gong 2010; Quer, Mazzoni & Sapountzaki 2010; Brentari 2010). The fourth sign language is the newly emergent Nicaraguan Sign Language (NSL); thus we can examine how historically related (LIS and ASL) and unrelated

Figure 1. Examples of Handling and Object handshapes.
(CSL) sign languages behave with respect to these two types of handshapes, and how a more recently
developed sign language (NSL) fits in.

In addition to the sign language analyses, we also will analyze the patterns produced by adult
gesturers from these four countries to understand potential differences in gesture systems in these
eighty very different cultures; these comparisons will allow us to determine if there are differences
across country that apply to both sign language and gesture. In the earlier work (Brentari et al., 2012),
sign language and gesture groups demonstrated different patterns from one another along the first of
the two dimensions studied here. In both Italy and the United States, signers showed higher selected
finger complexity in Object handshapes and lower selected finger complexity in Handling hand-
shapes. Gesturers showed the reverse pattern: higher selected finger complexity in Handling hand-
shapes and lower selected finger complexity in Object handshapes. Some differences across country
were also found but not further explored in the earlier work.

In the second study presented here, we examine the acquisition of finger group and joint
complexity in the handshapes produced by deaf child signers and hearing child gesturers in three
of the four countries from Study 1—Italy, the United States, and Nicaragua—to determine if there
are differences between children and adults.

These studies strengthen and extend previous work by analyzing two dimensions of handshapes—
joint complexity and finger group complexity—to see how the two types of handshape properties
interact with one another: (i) in gesture versus sign languages, (ii) across different sign languages that
are unrelated and have different historical depth, (iii) across different gesture systems from the
surrounding spoken language communities, (iv) in acquisition; and (v) across countries. The
following three sections present the background for handshape in morphosyntax and morphopho-
nology relevant for the current studies.

1.1. Properties of Handling and Object handshapes: Morphosyntax

Both handshape types under investigation are iconic. That is, there is a nonarbitrary relationship
between the form of the signs and their meaning. In Brentari et al. (2012) the term “hand-as-object”
is used to describe the iconicity in Object handshapes, since the shape of the hand assumes visual
properties of the object, such as straight, wide, or round. The term “hand-as-hand” is used to
describe the iconicity in Handling handshapes, since the hand represents the hand holding or
manipulating an object. These types of meaning are available to signers and gesturers alike by
means of the iconicity.

In spoken languages, sound symbolism is meaningful and often acoustically onomatopoetic but
rarely morphological (Hinton, Nichols & Ohala, 1994). In sign languages, iconic elements of handshape
exhibit morphological and syntactic properties as well (morphology: Supalla, 1982; Engberg-Pedersen
participate as productive morphological affixes of the classifier predicate systems of many sign
languages to the extent that they are stable across related contexts. These same handshapes are used
in other contexts where they have iconic meaning, including lexical items such as monomorphic nouns and verbs, but they behave as morphological elements only in classifier predicates (Brentari & Padden, 2001). In classifier predicates Handling and Object handshapes display syntactic oppositions as well; Handling handshapes are associated with clauses containing an agent, while Object handshapes are associated with nonagentive, particularly unaccusative clauses (Benedicto & Brentari, 2004)—e.g.,

There are several types of classifiers in sign languages; only three are relevant to our current
study: Handling, in which the handshape represents the hand that manipulates the object (Supalla,
1982); and two types of Object classifiers: Whole Entity, in which the handshape represents the object
as a whole or class of object rather than its parts (Engberg-Pedersen, 1993), and Size-and-Shape, in
which the handshape represents a subset of the properties of an Object (Supalla, 1982). Both whole
entity and size-and-shape constructions are referred to as Object classifiers throughout this article.
Object classifiers affix to sign movements that indicate either a specific location or a movement of an object. Examples are given in the following (1)–(3):

1. Handling classifiers
   (a) handle a flat object: \(\mathcal{V}\), all fingers bent only at knuckle joint
   (b) handle a small object: \(\mathcal{X}\), index bent at knuckle joint; pads of thumb and index touch

2. Whole Entity classifiers
   (a) vehicle: \(\mathcal{Z}\), thumb, index, and middle fingers extended
   (b) airplane: \(\mathcal{H}\), thumb, index, and pinky fingers extended

3. Size and Shape Specifiers
   (a) long-thin-object: \(\mathcal{B}\), index finger extended
   (b) small object: \(\mathcal{L}\), index finger curved

1.2. Properties of Handling and Object handshapes: Phonology

The hand is not treated as an undifferentiated whole in sign language phonology; handshape has several subcomponents. The representation of handshape includes a branch in the feature tree representing the “active,” “foregrounded,” or “selected” fingers in a given handshape (see Figure 2) versus those that are nonselected. Selected fingers are those that move or contact the body during the articulation of a sign. Modifications of selected fingers create minimal pairs in ASL and are important for the application of phonological rules in several sign languages, including ASL, Israeli Sign Language (ISL), and Nederlandse Gebarentaal (Sign Language of the Netherlands, or NGT) (Klima & Bellugi 1979; Hulst 1995; Meir & Sandler 2007). Moreover, the features of selected fingers form natural classes of handshapes, such as the index finger group \(\mathcal{\phi}\), which contains \(\phi, \dot{\phi}, \&\), \(\&\), and \(\&\) —i.e., all handshapes with only the index finger selected make up a natural class of handshapes (similar to the subgroupings of obstruents in English as they combine with the features of place of articulation, manner, and voicing).\(^1\)

The features of the Prosodic Model (Brentari 1998) involved in finger selection are the quantity and point of reference features (see Figure 2). The quantity features [one] and [all] specify how many selected fingers there are—one finger ([one]), two fingers ([one] dominates [all]), three fingers ([all] dominates [one]), or all fingers ([all]). The point of reference features [ulnar] and [mid] specify which side of the hand the selected fingers refer to: the default is the radial surface of the hand (index finger side), if the selected fingers refer to the middle or pinky finger side of the hand, it is specified as [mid] or [ulnar] respectively. The relevant features involved in joint configuration in the Prosodic Model (Brentari 1998)

![Figure 2. Joint configuration and finger selection in the handshape structure of the Prosodic Model (Brentari 1998).](image)

\(^1\)We use the handshape font (e.g., \(\&\)) to indicate handshapes. When used for individual handshapes, the image is a picture of a particular hand. When this font is used to represent finger groups, the image stands for a category of handshapes. In these cases, the term “finger group” will precede the image (i.e., “finger group \(\&\)”), and the image will picture a handshape with extended fingers, without the thumb. For example, the finger group \(\&\) represents the set of handshapes that includes the range of configurations with the index and middle finger selected: \(\phi, \dot{\phi}, \&\), \(\&\), \(\&\), and \(\&\).
are [flexed], which can apply to the base (knuckle) or nonbase (interphalangeal) joints of the hand, as well as [spread], [stacked], and [crossed] (see Figure 2). The feature [flexed] plus the structures for base and nonbase joints generate seven aperture positions from fully closed to fully open: fully closed, flat closed, curved closed, flat open, curved open, bent, and fully open.

1.2.1. Handshape complexity
The criteria for determining handshape complexity in terms of selected finger group and joint configuration is based on a number of factors, including frequency (Hara 2003; Eccarius & Brentari 2008), complexity of structure in terms of the number of branches and features in the phonological structure as described previously, and age of acquisition (Boyes Braem 1990). In general, higher finger group complexity indicates a larger and more adultlike inventory of handshapes in acquisition (Marentette & Mayberry 2000). Examples of low-, medium-, and high-complexity handshapes for both joint configuration and finger selection are given in Figure 3.

1.2.1.1. Joint complexity. The low joint complexity handshapes are the most frequent—fully extended or fully flexed (e.g., ☯ is a fully open handshape and ☯ is a fully closed handshape [Figure 3, left, bottom]). These are also among the earliest handshapes acquired by children learning ASL acquisition (Boyes Braem 1990) and British Sign Language (Morgan, Barrett-Jones & Stoneham 2007). The most complex joint configurations are the most infrequent, the latest acquired, and the least frequent cross-linguistically (Geraci et al. 2015)—stacked and crossed (e.g., ☩ [stacked] and ☦ [crossed] [Figure 3, left, top]). The other joint specifications—flat closed ☪, flat open ☬, curved closed ☬, curved open ☬, bent ☬, and spread ☬ handshapes—are all designated medium-complexity handshapes for our purposes here (Figure 3, left, middle).

1.2.1.2. Finger group complexity. Likewise, handshapes with low finger group complexity (Figure 3, right, bottom) are the most frequent cross-linguistically, are among the earliest acquired by native signers, and have the simplest phonological representation. They include the groups with all fingers (finger group ☯), the index finger (finger group ☯), and the thumb (finger group ☯).

![Figure 3](Image) Examples of handshapes exhibiting different levels of joint complexity (left) and finger group complexity (right). The handshapes illustrating joint configurations are all variants of the B-handshape, with all of the fingers selected, or the U-handshape, with two fingers selected. The handshapes illustrating finger group complexity have fingers that are fully extended (selected), with the closed fingers being unselected.
These finger groups account for a high proportion of handshapes in ASL (81%) and in many other sign languages as well (Hara 2003). Medium finger group complexity handshapes (Figure 3, right, middle) include one additional structural elaboration: either a second selected finger on the radial (thumb) side of the hand (the default side), as in finger group \( \text{Handshape}_1 \), or a single selected digit that is not on the radial side, as in the pinky or middle finger groups \( \text{Handshape}_2 \) and \( \text{Handshape}_3 \). High finger group complexity handshapes (Figure 3, right, top) include all remaining finger groups, which are less frequent and have more complex phonological structures.

1.3. Properties of Handling and Object handshapes: Morphophonology

Handling and Object classifier handshapes might or might not be paralleled by a corresponding phonological pattern. Using joint configuration as an example, let us consider a hypothetical situation in which a given sign language were to use the following set of handshapes as Object classifier handshapes—\( \text{Handshape}_1 \). This set would not only be a morphological class but would also form a phonological class because the selected fingers in each handshape share a phonological property—namely, they are all fully open (“extended”). If a signer of this sign language were to encounter new handshapes, such as \( \text{Handshape}_2 \) or \( \text{Handshape}_3 \), these would be predicted to belong to the “Object” class because of this phonological generalization. In contrast, if a second hypothetical sign language were to use this set of handshapes for whole entity classifiers—\( \text{Handshape}_4 \)—the set could still be a morphological class, but it would not form a phonological class, as there is no common joint property that the handshapes share (see Figure 4); that is, the handshapes in this class would mark a specific class of meanings (whole entities) but would lack a corresponding phonological property that unifies them. In this second case, a signer could not predict from the handshape structure the morphological class to which it belongs.

Spoken languages also exhibit cases that are both phonological and morphological. For example, Arapeshan (Fortune 1942; Dobrin 1997): The singular and plural forms of gender class morphemes are generally paired with one another, and the plural form typically has more phonological complexity than the singular form (4). This phenomenon is comparable to the phenomena we are studying in Object and Handling handshapes: There is clear systematic variation at the morphological and phonological levels, but the morphology and phonology change together rather than independently.

(4) Arapeshan gender marking (see Dobrin 1997)

<table>
<thead>
<tr>
<th>Gender Class</th>
<th>Singular</th>
<th>Plural</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. I</td>
<td>ahorby 'knee'</td>
<td>ahorbys 'knees'</td>
</tr>
<tr>
<td>b. VI</td>
<td>lawan 'tree snake'</td>
<td>lawanab 'tree snakes'</td>
</tr>
<tr>
<td>c. XI</td>
<td>alit 'shelf'</td>
<td>alitog 'shelves'</td>
</tr>
</tbody>
</table>

Figure 4. A group of hypothetical handshapes that would constitute a morphological and phonological class (left) and another group that would constitute only a morphological class (right).
Two morphophonological sign language handshape patterns of the sort described here pertain to finger complexity and joint complexity. Both were first observed by Eccarius (2008) and Brentari and Eccarius (2010) for three historically unrelated sign languages: ASL, Swiss German Sign Language (DSGS), and Hong Kong Sign Language (HKSL). Selected finger complexity was higher in Object Handshapes and lower in Handling handshapes, and joint complexity was higher in Handling handshapes and lower in Object handshapes. While not every Handling handshape has lower finger group complexity and higher joint complexity than every Object handshape, these generalizations about the average complexity for each handshape class can predict where new entries into the system belong morphologically. One of these patterns—finger group complexity—was later studied in a larger, more controlled elicitation study in ASL and LIS (Brentari et al. 2012). In the current study we seek to replicate these findings, as well as add the dimension of joint complexity.

Shifting now to language emergence, Brentari et al. (2012) also demonstrated that the signers’ pattern in LIS and ASL (again in finger complexity only) differs from that of hearing people’s gestures in Italy and the United States respectively. In gesture, a pattern opposite to that of the sign languages was observed: Object handshapes exhibited lower finger group complexity, and Handling handshapes showed higher finger group complexity. Importantly, adult homesigners in Nicaragua exhibited a pattern that is closer to that of the sign language groups, suggesting that this form-to-form relationship occurs quite early in the emergence of language and that the sign language pattern was arrived at via a systematic process of phonologization. Furthermore, a longitudinal study of a single child homesigner over a five-year period confirmed this finding; in this young homesigner, sign language-like finger complexity appeared between the ages of 11 and 12 years (Coppola & Brentari 2014).

In the following two investigations, we use a controlled elicitation task with sixty-nine adult and child participants, including deaf signers and hearing gesturers from four countries: Italy, the United States, China, and Nicaragua, to address the following questions:

(i) Are these patterns robust across sign languages and truly different from that of local gestures? Specifically, are joint and finger group complexity used to form phonological oppositions between meaningful handshape types (i.e., Handling and Object) within a system?
(ii) Are there cross-linguistic differences among the sign groups, and particularly, to what degree are these patterns evident in a newly emergent sign language?
(iii) Are there cross-cultural differences among the gesture groups?
(iv) Are these patterns evident in child language? If so, are they acquired before or after the corresponding morphological system is in place?
(v) Are there patterns shown by participants in specific countries that might indicate a general gestural competence shared by both gesture and sign language?

2. General methods
The stimuli, data collection, and coding procedures are the same for all three studies and are the same as those used in Brentari et al. (2012). They will be described here in a general methods section. The participants for each study will be described separately in each of the studies.

2.1. Stimuli
The stimulus items were drawn from a set of 131 photographs and short videos (henceforth vignettes), each of which featured one of eleven object types: toy airplanes, books, cigars, lollipops, marbles, pens, strings, tapes, television sets, and tweezers. The actual objects depicted in the stimulus clips exhibited a range of colors, shapes, and sizes. Each object type was portrayed in ten conditions:
five depicted a stationary object or an object moving on its own without an agent, and five depicted an object being moved by the hand of an agent (Figure 5). Not all items were collected from all groups, and because we will be comparing fourteen different groups across both studies, we confine our analyses to a set of thirty-one stimulus items that were collected from every participant in each of the fourteen groups: the full set of conditions for the objects airplane and lollipop, plus all of the objects in the condition where the object was falling from the table.

2.2. Procedures

Gesturers were instructed to “watch each video and describe what you see using your hands and without using your voice.” Signers were instructed in their respective sign language to “watch each video and describe what you see.” Data collection sessions were videotaped, and the video files containing the participants’ responses were transcribed using ELAN (Crasborn & Sloetjes 2008).

2.3. Coding

A given trial could elicit multiple signs or gestures. Most signers first labeled the object in the vignette with a noun, before producing one or more verbs (containing a classifier affix) to describe the event. As our focus is on the event description, we did not include these nouns in our analyses. To make the comparable cut for the gesturers, we segmented their responses into gestures used to label the object (typically gestures produced on the body or in neutral space—that is, without reference to a specific location) and gestures used to describe the event or spatial arrangement shown in the vignette (gestures that moved or were situated at a particular location). This type of distinction could be made without difficulty, given that we were using a controlled task. We analyzed only the signs or gestures that expressed the state or event shown in the vignette. Each

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<table>
<thead>
<tr>
<th>Scenes without an agent</th>
<th>Scenes with an agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. [object] on table upside down</td>
<td>7. Put [object] on table upside down</td>
</tr>
<tr>
<td>3. Multiple [objects] on table  (regular arrangement in row/s)</td>
<td>8. Put multiple [objects] on table  (regular arrangement in row/s)</td>
</tr>
<tr>
<td>5. [object] falling</td>
<td>10. Demonstrate function of [object]</td>
</tr>
</tbody>
</table>

Figure 5. Description and examples of stimulus objects and conditions. The pictured conditions (3 and 8) are the ones in bold italics above the photos.

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2This task is also used with homesigners, as reported in other studies (Brentari et al. 2012; Coppola & Brentari 2014; Goldin-Meadow et al. 2015), necessitating minimal instructions; for consistency instructions were minimal with all groups.
handshape was first coded in terms of the class of handshape to which it belonged, regardless of
the stimulus: Handling handshapes represented the manipulation or handling of the object; Object
handshapes represented the whole object, part of the object, or physical characteristics, such as size
and shape, of the object. Handshapes that were not relevant to our analyses and were thus
excluded were: the index finger or neutral handshape used to trace the object’s path or indicate
its location; the whole body used to substitute for an object in motion (e.g., falling off the chair to
indicate the object falling); or lexical verbs (such as FALL), rather than classifier predicates
(relevant only to signers).

Each handshape was then transcribed according the notation system developed in Eccarius and
Brentari (2008) and assigned separate joint and finger group complexity scores using the criteria
described previously in section 1.2.1: low (1), medium (2), or high (3). A handshape was given an
extra point each for complexity of fingers or joints if there was a change in the dimension in
question in a single gesture or sign. For example, if the handshape changed from one joint
configuration to another—\( \text{Y (V-handshape)} \) to \( \text{X (R-handshape)} \), or \( \text{x (B-handshape)} \) to \( \text{V (B[flat]\-handshape)} \)—an extra point of joint complexity was added. If the gesture or sign began using all
of the fingers and ended in a handshape using only one finger—e.g., \( \text{B (handshape)} \) to \( \text{Y (V-handshape)} \)—an extra point of finger group complexity
was added. Thus, values for finger group or joint complexity ranged from 1 to 4.

The interlocutor was either a native signer or speaker, or in the case of NSL, a peer from the same
cohort. For each study, annotation was performed by a team of trained annotators based in the
laboratory of the first author. All had at least three months of training on the coding system, until
they reached a threshold of reliability on a standard set of items. Reliability was assessed on the
coding of specific handshape form (i.e., which of over 100 possible handshapes was the best match
for the produced handshape) and for handshape type (Object, Handling, or neither [e.g., a point or
lexical verb]). Coders were assessed on data from one participant from each group, for one stimulus
object (e.g., airplane). Agreement between coders was at least 90% for both handshape form and
handshape type.

3. Study 1: Adult sign language vs. gesture groups (four countries)

In Study 1 we ask whether the patterns of finger group and joint complexity are different across
languages and cultures in adults. We selected Italy, the United States, China, and Nicaragua for
comparison, for several reasons. Regarding gesture, the gesture systems of Italy and Nicaragua
include a rich set of types of manual gestures (including pragmatic and emblematic gestures) and
have been called “gesture-rich” cultures, compared to the United States (Kendon 2004) or China. If
some gesture systems could be found to show a signlike pattern, we might expect it to be within such
a culture.

Regarding the sign languages chosen, we sought to compare sign languages that are completely
unrelated (LIS, ASL vs. CSL), that may be related (LIS, ASL), and that differ in their historical depth
(ASL, LIS, CSL vs. NSL). The Shanghai variety of CSL is totally unrelated to ASL, NSL, and LIS. The
first school for the deaf in Shanghai dates from 1892 (Fischer & Gong 2010). ASL and LIS are
remotely related, and likely both share some influence of the sign language used in France by means
of a network of European clergy who established schools in the first half of the 19th century (Quer,
Mazzoni & Sapountzaki 2010). The historical contexts are quite a bit different, however. Gallaudet
traveled to Paris and brought back Laurent Clerc (a signer of French Sign Language) to assist him in
establishing the first American school, and Clerc’s presence had an effect on ASL as it emerged (Lane
1984), while Silvestri did not bring a Paris school graduate back to Italy. Historians, therefore, infer
that Silvestri’s methods were applied more directly to what Italian signers were already using at the
time (Corazza 1993; Quer, Mazzoni & Sapountzaki 2010).

NSL is a newly emergent sign language that arose naturally within a social community of deaf
children and adolescents in Managua, the capital of Nicaragua (Kegl & Iwata 1989; Senghas 1995).
Prior to the 1970s, deaf individuals in Nicaragua had few opportunities to interact with one another. Most deaf individuals were isolated in their homes, and the few schools and services available served small numbers of children and adolescents, without leading to extensive social contact outside of school hours. In this context, no sign language emerged, evidenced by the lack of a shared language in deaf adults over the age of 50, even today. These homesigning individuals have neither a language community nor a language model. In the late 1970s and early 1980s, rapidly expanding special education programs in Managua brought many deaf individuals together for the first time. Initially, approximately 50 deaf children were enrolled; this number increased to over 400 by the mid-1980s (Polich 2005). Although all instruction at that time was conducted in spoken Spanish, students were able to freely communicate with each other using gestures. As they interacted socially on school buses, in the schoolyard, and later in their homes, they converged on a common system of signs, and a new sign language was born. At this stage, these signers had a community but not a language model and are often referred to as Cohort 1 signers. The language continued to develop and change, increasing in grammatical complexity as new waves of children entered the community each year and learned to sign from older peers (Senghas & Coppola 2001; Senghas, Kita & Özyürek 2004) with the benefit of both a language community and a language model to Cohort 2 signers and beyond. We chose Cohort 2 signers for our study because they are the “earliest” group with both a language model and a linguistic community. We wanted the NSL signers to be as similar to the ASL, LIS, and CSL signers as possible except for the factor of language age, so this was the optimal comparison group.

3.1. Participants

Forty-four adults participated in this study: twenty-two signers and twenty-two gesturers. For ASL, LIS, and CSL, all signers were native users of the target language (having at least one Deaf signing parent), use their respective sign language as their primary language, and are active members of their respective Deaf communities. The six ASL signers are from the Midwestern area of the United States (age range 27–56 years, M = 41); the six LIS signers are from the greater Milan area (23–39 years, M = 33); the five signers of CSL are from Shanghai (27–32 years, M = 30), and the five signers of NSL are from Managua (19–24 years, M = 22). The NSL signers had all been first exposed to NSL between 4 and 6 years of age. They are also active participants in the Deaf community.

Twenty-two adult, hearing gesturers also participated: six Italians from the Tuscany region (20–29 years, M = 24), six Americans from the Midwestern area of the United States (20–25 years, M = 23), five Chinese individuals from Shanghai (21–31 years, M = 26), and five Nicaraguans from Estelí, a city in the north of Nicaragua (18–30 years, M = 22). None of the hearing gesturers is familiar with a sign language, nor do they have any deaf members in their families.

3.2. Analysis and results

Study 1 asks whether signers and gesturers use joint and finger complexity differently for Object and Handling handshapes and whether there are important cross-linguistic differences (for the sign groups) or cross-cultural differences (for the gesture groups). The overall data set contained 2,537 data points from the forty-four participants. Multiple gestures/signs within a single event description portion were included in the analysis. Two linear mixed-effects models were used (Baayen, Davidson & Bates 2008), one with joint complexity as the dependent variable and one with finger group complexity as the dependent variable. In each model, Type of System (Sign language, Gesture), Handshape Type (Object, Handling), and Country (United States, China, Italy, Nicaragua) were treated as fixed effects. Random intercepts for Participant, Stimulus Object, and a by-Stimulus-Object random slope for the three-way interaction of Type of System x Country x Handshape Types were included as random effects (Barr et al. 2013). No correlation between the random effects was assumed. The difference in complexity between Object handshape and Handling handshape (a factor
internal analysis) was also analyzed to see if there was a significant difference in the way that the two types of handshape were used in each group for joint and for finger group complexity. We used the R statistical computing environment (R Core Team 2014) and lme4 (Bates, Mächler & Walker 2015) to perform the analyses. In all F-tests, the Kenward-Roger approximation method was applied to adjust the denominator degrees of freedom.3 The Benjamini-Hochberg procedure (Benjamini & Hochberg 1995) was applied to account for multiple testing in post hoc comparisons. The results of both the joint and finger complexity analyses are shown in Figure 6.

3.2.1. Joint complexity
Joint complexity showed significant effects for Type of System ($F = 6.315, \text{ndf} = 1, \text{ddf} = 71.670, p < .01$), where the gesture groups had higher joint complexity than the sign groups, and for Handshape Type ($F = 241.091, \text{ndf} = 1, \text{ddf} = 438.150, p < .0001$), where Handling handshapes showed higher joint complexity than Object handshapes. There was also an interaction of Type of System and Country ($F = 4.917, \text{ndf} = 3, \text{ddf} = 71.630, p = .004$), where the gesture group had higher joint complexity than the sign group in Nicaragua, Italy, and United States, while the sign group had higher joint complexity than the gesture group in China.

Post hoc pairwise comparisons suggest that all sign language and gesture groups showed significantly higher joint complexity for Handling than Object handshapes (all $p$s < .0001), and the Chinese gesture group had lower joint complexity than the Italian and Nicaraguan gesture groups in Object handshapes ($p = .013$). There were no other significant effects or interactions.

Examples of handshapes from the adult groups with high joint complexity are shown in Figure 7.

3.2.2. Finger group complexity
There was a significant difference for Type of System, where signers had higher finger group complexity than gesture groups ($F = 5.597; \text{ndf} = 1; \text{ddf} = 153.017; p = .02$), and for Handshape Type, where Object handshapes showed higher finger complexity than Handling handshapes ($F = 22.415; \text{ndf} = 1; \text{ddf} = 393.386; p < .0001$). There was a significant interaction between Handshape Type and Type of System ($F = 50.631; \text{ndf} = 1; \text{ddf} = 362.762; p < .0001$), where Object handshapes showed higher finger complexity than Handling handshapes, specifically for sign groups. In addition, the interaction between Handshape Type and Country was significant ($F = 4.152; \text{ndf} = 3; \text{ddf} = 361.656; p < .01$), where Object handshapes had higher finger complexity than Handling handshapes in China, the United States, and Nicaragua, but the Handling handshape had higher finger complexity than the Object handshape in Italy.

In all F-tests, the Kenward-Roger approximation method, implemented in pbkrtest (Halekoh & Højsgaard 2014), was applied to adjust the denominator degrees of freedom.

Figure 6. Adult joint and finger group complexity in the United States, China, Italy, and Nicaragua. Estimated joint complexity (left) and finger group complexity (right) for each group, with standard error bars. The symbol (circle for handling handshapes or triangle for object handshapes) indicates the mean. Because these are estimated values provided by the model, values can be less than 1, which was the minimum finger or joint complexity value in our system.
Post hoc pairwise comparisons suggest that all of the sign groups showed higher finger group complexity in Object handshapes than in Handling handshapes (all $p < .05$). The Italian gesture group also showed a significant difference between Object and Handling handshape finger group complexity, ($p = .02$), but in the opposite direction: Handling handshape finger group complexity was greater than Object handshape finger group complexity. Post hoc pairwise comparisons of finger group complexity, specifically for Object handshapes, also showed significant differences between CSL and LIS, between CSL and NSL, between ASL and LIS, and between ASL and NSL (all $p < .05$). There were no other significant effects or interactions. Examples of handshapes from the adult groups with high and medium finger group complexity are shown in Figure 8.

3.3. **Discussion: Study 1**

The goals in Study 1 were to determine whether different types of systems (sign language vs. gesture) showed different patterns of joint and finger complexity, as well as differences among the sign groups, among the gesture groups, or among the countries. Three major findings emerged. First, signers’ handshapes are not more complex than those of gesturers overall, but in sign languages the complexity is distributed more equally across the two handshape types. Sign languages reduce the amount of joint complexity that is sufficient to capture the number of categories the language requires and no more. The distribution of their complexity has become more balanced and is directed in a systematic way toward the two handshape types—joint complexity is associated with Handling handshapes and selected finger complexity with Object handshapes. Second, signers and gesturers have the same pattern with regard to joint complexity—higher in Handling handshapes,
lower in Object handshapes. In contrast, the finger group complexity patterns differ between the two groups—signers show higher finger complexity in Object handshapes while gesturers do not. Third, the emerging sign language, NSL, exhibits the same pattern as the three well-established sign languages.

Before discussing the quantitative results in detail, there is an interesting observation worth noting about productions that included a change in joint or finger group complexity. Although a sign in ASL may undergo a change in joint specification and still be well formed, there is a stronger tendency in the sign groups not to change the joint value in their productions compared with the gesturers (average 8% for sign groups; average 21% for gesture groups). In other words, the gesture groups more often produced forms consisting of an open or flat form changing to a stacked or closed form, which resulted in an additional complexity point for joints. With regard to finger group complexity, ASL has a restriction on changing from one finger group to another within a sign (Sandler 1986; Brentari 1998). For example, a high Object handshape finger complexity form such as or cannot change to a form, which would gain that form an extra complexity point. Here we see that neither signers nor gesturers produced forms with changes in finger group very frequently (average 1% for sign groups; average 4% for gesture groups); nonetheless, for every pair of groups by country, the sign group produces fewer changes than the corresponding gesture group.

### 3.3.1. Joints

Higher joint complexity occurs in Handling than Object handshapes in all groups. We suggest that the affinity between joint complexity and Handling handshapes is gestural rather than linguistic, as well as iconic, and that it may also be the starting point for phonologization in signers. In other words, the manual modality has a very strong affinity between the use of joints to show manipulation of objects, and gesturers access iconic gestures via action (Piaget 1952), where hands represent hands, in hand-as-hand iconicity. Though this study concerns adult data, the argument that handling handshapes are associated with action accords with Marentette and Nicoladis (2011), who found that as soon as children become sensitive to the iconicity inherent in gesture, their default assumption is that gestures are action associates; that is, an “action bias” in iconicity appears quite early in acquisition. We will see if this bias is already in place in the child participants in Study 2.

The gesture groups show some significant differences among them. The Nicaraguan and Italian gesture groups show higher joint complexity, particularly in Handling handshapes, than the Chinese gesturers, showing that even if there are broad similarities across all gesture groups, there are also differences among them at a finer-grained level.

### 3.3.2. Selected finger groups

Of the properties analyzed in this work, there are no patterns of finger group complexity that signers and gesture groups share. All sign groups show higher finger group complexity in Object than Handling handshapes, but gesturers do not show this pattern. One of the striking findings is that NSL shows the same overall pattern as the more established sign languages, so it is clear that this restructuring happens quite early in the emergence of a language. This concurs with the findings of Brentari et al. (2012) for ASL and LIS, as well as the findings with four adult homesigners, and of Coppola and Brentari (2014), with a single child homesigner studied longitudinally (ages 7–12 years).

Another interesting finding is that, focusing on the sign groups, the post hoc comparisons suggest that CSL and ASL pattern in ways that are more similar to each other, and that LIS and NSL also pattern together. Further analysis is needed on the potential typological groupings of sign languages based on such phonological differences.

Focusing on the gesture groups, only the Italian gesture group showed a significant difference between Object and Handling handshapes, but in the opposite direction than the sign groups; i.e., higher finger complexity in Handling handshapes than in Object handshapes. This helps to further confirm and clarify the result found in Brentari et al. (2012), where gesturers also had a significantly higher degree of finger group complexity in Handling than Object handshapes. It appears that in
many gesture groups, there is not enough finger group complexity in any handshape type for this
difference to be manifest. In other words, gesturers often will not display any finger group complex-
ity, but if they do, it is predicted to appear in Handling handshapes and to align with the results from
the Italian gesture group. It appears that the link between action and gesture leads gesturers to
channel all of their complexity into Handling handshapes and to virtually ignore complexity in
Object handshapes.

On a final note, it is quite interesting that the countries where gesture groups pattern together on
joint complexity (Italy and Nicaragua) are the same as those sign groups that pattern together with
regard to finger group complexity. These correlations across country would be interesting to pursue
in future work because they hint at some common properties across country that have not been
uncovered with this task.

In summary, we are not arguing that sign languages have more complex handshapes than
gesturers overall; rather, our general findings support the view that sign languages undergo a fairly
radical restructuring of the surrounding gesture system, resulting in a qualitatively different,
predictively patterned system. Iconicity is not ignored but is shaped into a system that can
accommodate a wider range of meanings and phonological contrasts for those meanings—in other
words, an efficient system that does not excessively tax the production and perceptual systems. By
using the gesture groups for comparison, we see that phonologization in the sign groups involves
losing some of the joint complexity in Handling handshapes and increasing finger complexity in
Object handshapes, and we would argue that since sign languages have both hand-as-hand and
hand-as-object iconicity, the overall morphophonological pattern of sign languages is to create a
division of labor such that Handling handshapes are associated with joint complexity, and Object
handshapes come to be associated with finger group complexity.

4. Study 2: Child signers and gesturers in Italy, the United States, and Nicaragua

This brings us to the question of the origin of these patterns in acquisition. The aim of study 2 is to
compare children’s patterns of finger complexity to those found in adult signers and gesturers from
the corresponding groups. Do the two types of features (joint and finger selection) travel together or
separately? Do the different handshape types arise in response to a need to mark different morpho-
logical types—in this case, the different categories of morphological classifiers? Or does the variety of
forms emerge first, available to be mapped to the distinctions in morphology as they are acquired?
That is, which comes first in acquisition, the phonology or the morphology? This is a question about
how a child learner breaks into the system. We know from previous work that the distinction
between Handling and Object handshapes as markers of agentive vs. nonagentive clauses appears
sometime between age 7 and 9 years of age (Schick 1987; Brentari et al. 2013). We turn to child
signers and gesturers in Italy, the United States, and Nicaragua, to see if the pattern of handshape
complexity is evident early, even before the morphological contrast associated with Handling and
Object handshapes is typically fully acquired.

All children studied were immersed in their respective sign languages for four to six years prior to
testing. Deaf Nicaraguan children are typically first exposed to their sign language when they enter
school, so they were tested at age 10, having four to six years’ exposure to NSL, comparable to the
number of years of exposure of the 3- to 6-year-old LIS and ASL children. This age range was chosen
because, by this time, the acquisition of handshape from the phonological point of view is thought to
be complete (Boyces Braem 1981, Marentette & Mayberry 2000); however, the acquisition of the
agentive/nonagentive clause distinction is ongoing during this period in ASL (Supalla 1982; Schick
1987; Brentari et al. 2013; Brentari et al. 2015).

From a purely phonological point of view, the acquisition of handshape follows a time course
from approximately twelve to forty-eight months that is best explained by the principles of ease of
articulation and ease of perception (Boyces Braem 1990; Conlin et al. 2000; Marentette & Mayberry
2000; McIntire 1977). Handshapes that are easier to produce and perceive are acquired earlier than
handshapes that are more difficult to produce and perceive. Kantor (1980) and Fish et al. (2003)
helped to refine these findings of handshape acquisition in classifiers, showing that handshape
complexity alone cannot explain children’s classifier handshape errors. They concluded that other
factors may also be involved, particularly the use of the same handshapes within a second morpho-
logical system (in the productive classifier system), as well as within the phonological system (in core
lexical signs). Kantor (1980) investigated the acquisition of complex handshapes, such as $\text{Z}$, and
found that they are used first in core lexical items and only later in classifier predicates.

There is an extensive literature on the general acquisition of classifier predicates in ASL. This
previous work shows that classifier predicates are learned between the ages of 3;00 and 9;00 (years;
months), morpheme by morpheme (rather than as unsegmented wholes; Ellenberger & Steyaert
Newport 2004). The specific morphosyntactic system associated with the agentive/nonagentive
opposition addressed here first appears between ages 4 and 6 years, but is not fully mastered until
ages 7;00–10;00 in ASL (Schick 1987; Brentari et al. 2013).

4.1. Participants

Twenty-five children (eleven signers and fourteen gesturers) from Italy, the United States, and
Nicaragua participated. Four child signers from Italy (LIS) ranged in age from 3;10–6;00 ($M = 5;02$)
and attended a bilingual, bicultural educational program in Rome. Two ASL signers from the greater
Indianapolis area participated once per year for three years (ages 4;01–6;04); their data were pooled
across testing sessions.\(^4\) The third ASL signer participated once (4;04). All three were attending the
Indiana School for the Deaf, a bilingual, bicultural educational program in which the goal is for
children to master both ASL and (written) English. All ASL and LIS signers had Deaf signing parents
and used their respective sign language as their primary language. The four NSL signing children were
from Managua (ages 10;01–10;08, $M = 10;05$); they were chosen specifically because they have had four
to six years of exposure to NSL and in this way are closest in language experience to the LIS and ASL
child signers. They are Cohort 3 signers, according to the description from Study 1; that is, they have
both a linguistic community and a language model, and they had as their model signers from Cohort 2.
The gesture groups consisted of three Italian children from Rome and one from the Tuscany region
(ages 4;06–5;03, $M = 4;11$), three American children from the greater Los Angeles area (ages 4;03–4;08,
$M = 4;05$), and seven children from Estelí, a city two hours north of Managua (5;00–10;08, $M = 7;04$).
None of the gesturing children had been exposed to sign language.

4.2. Results

The child data were subjected to the same analyses as those in Study 1, first alone (945 observations),
and then combined with the adult data from the corresponding groups in the three countries (2,975
observations). We again used a linear mixed-effect model to analyze the effects of Type of System,
Country, Handshape Type, and Age on joint and finger group complexity.

The results for both the joint and finger complexity analyses are shown in Figure 9.\(^5\)

4.2.1. Joint complexity

When the child data were analyzed alone, joint complexity showed significant effects for Handshape
Type ($F = 101.793$; $ndf = 1$; $ddf = 328.422$; $p < .0001$), with higher joint complexity for Handling than
Object handshapes overall. In addition, there was a significant three-way interaction among Type of
System, Handshape Type, and Country ($F = 5.266$, $ndf = 2$, $ddf = 265.545$, $p = .0057$); the complexity
difference between Handling and Object handshapes was less in the Nicaraguan gesture group than

\(^4\)These data were analyzed separately for each year and each participant. Finding no differences by year, the data were pooled.
\(^5\)The estimated means differ slightly in study 1 and study 2 because they are affected by the comparison groups.
in the sign group and greater in the US gesture group than in the sign group. Pairwise comparisons suggest that joint complexity was higher for Handling than for Object handshapes in all groups (all ps < .001).

When the combined data were analyzed (adults and children), joint complexity showed significant effects for Handshape Type ($F = 270.086, \text{ndf} = 1, ddf = 755.025, p < .0001$), with higher joint complexity for Handling than for Object handshapes, and Type of System ($F = 8.760, \text{ndf} = 1, ddf = 82.950, p = .004$), with higher joint complexity for the gesture groups than for the sign groups. In addition, there was a significant four-way interaction effect among Type of System, Handshape Type, Country, and Age ($F = 5.284, \text{ndf} = 2, ddf = 659.655, p = .005$). Looking at Figure 9, this effect is apparently due to the Nicaraguan child and adult gesture groups, which show a more noticeable difference than the other child-adult group comparisons. Examples from the child groups of handshapes with high joint complexity are shown in Figure 10.

4.2.2. Finger group complexity

When the child groups were analyzed alone, there was a significant difference for Type of System ($F = 11.715; \text{ndf} = 1; ddf = 35.262; p = .001$); where sign groups showed higher average finger group complexity overall than gesture groups, and for Handshape Type ($F = 6.988; \text{ndf} = 1; ddf = 314.352; p = .008$), where Object handshapes had higher finger complexity than Handling handshapes. There was a significant interaction of Handshape Type and Type of System ($F = 27.572; \text{ndf} = 1; ddf = 279.420; p < .0001$), with sign groups showing higher average finger complexity than gesture groups, specifically in Object handshapes. In addition, the three-way interaction among Handshape Type, Type of System, and Country was significant ($F = 3.489, \text{ndf} = 2, ddf = 266.059, p = .032$), with the American sign group showing a greater difference between Handling and Object handshapes than the Nicaraguan or Italian sign groups. Pairwise comparisons revealed that finger group complexity was higher for Object than for Handling handshapes in each of the three child sign language groups ($p < .05$), but not in the three child gesture groups.

When combined with the adult groups, the main effects of Type of System and Handshape Type were significant: finger complexity was higher in the sign group than in the gesture group ($F = 11.971, \text{ndf} = 1, ddf = 126.065, p = .0007$) and higher in the Object than in the Handling handshapes ($F = 15.284, \text{ndf} = 1, ddf = 653.678, p = .0001$). There were significant two-way interactions between

![Figure 9. Child and adult joint and finger group complexity in the United States, Italy, and Nicaragua. Estimated adult (top) and child (bottom) joint complexity (left) and finger group complexity (right) for each group with standard error bars. The symbol (circle for Handling handshapes or triangle for Object handshapes) indicates the mean.](image-url)
Type of System and Handshape Type ($F = 64.348$, $ndf = 1$, $ddf = 597.916$, $p < .0001$) and between Type of System and Age ($F = 5.230$, $ndf = 1$, $ddf = 126.034$, $p = .024$), where the difference between child gesture and sign groups was larger than between adult gesture and sign groups; and between Handshape Type and Country ($F = 5.272$, $ndf = 2$, $ddf = 591.987$, $p = .005$). There was also a three-way interaction among Type of System, Handshape Type, and Country ($F = 4.314$, $ndf = 2$, $ddf = 592.264$, $p = .014$). Examples from the child groups of handshapes with medium and low finger group complexity are shown in Figure 11.

4.3. Discussion: Study 2

The productions of the children in study 2 reveal important new information, beyond what we learned about adults in study 1. First, finger group complexity shows a stronger effect of age than joint complexity. Specifically, there is an even greater difference in finger group complexity between the child gesture and sign groups than between the adult gesture and sign groups. This suggests that the finger group complexity pattern is still undergoing change between childhood and adulthood. In contrast, for joint complexity only the Nicaraguan gesture groups showed an effect of age. The similar use of joint complexity in gesture and sign suggests that it follows naturally as an extension of manipulating objects. Moreover, the joint complexity pattern evidently stabilizes earlier than the period studied here, a finding consistent with Marentette and Nicoladis (2011), who showed that the patterns of action bias in iconic association emerge between the ages of 2 and 4.

Figure 10. Examples of handshapes showing two levels of joint complexity. A child NSL signer uses a medium joint complexity handshape to show a book on a table (left), and a child Italian gesturer uses a high joint complexity handshape to show a toy airplane being put upside down on a table (right).

Figure 11. Handshapes produced by children showing a toy airplane on a table. The LIS signer uses a handshape with medium finger group complexity (left), and the American gesturer uses a handshape with low finger group complexity (right).
These results also indicate that the phonological patterns studied here are acquired in signing children prior to the morphosyntactic distinction of Handling handshape for agentive clauses and Object handshapes for nonagentive clauses. We know from previous research on first language (L1) acquisition of ASL that the use of Object and Handling handshapes to mark the morphosyntactic, agentive distinction in classifier constructions is not mastered until between 7 and 9 years of age (Schick 1987; Brentari et al. 2013). The same 4–6-year-old participants from the Brentari et al. (2013) study participated in the current study and showed evidence of the phonological finger group complexity pattern.

Further evidence of this phonological distinction coming before the morphosyntactic one comes from language emergence. Coppola and Brentari (2014) found in a single child homesigner that the finger group complexity (phonological) pattern described here appeared in the homesigning child at 11;04, while the morphosyntactic pattern seen in adult signers was not present even at age 12;08. This dissociation indicates that these two aspects of the grammar are independent, even as they appear in the same handshapes, and that along these two dimensions phonology precedes morphology. It may be that the phonological distinction assists children in assigning the handling and object classifier handshapes to their appropriate category in later acquisition.

Considering these findings, in future work it will be interesting to investigate the phonological distinction described here in core lexical noun and verb signs (Kantor 1980; Fish et al. 2003) to see if the finger complexity difference found in such “frozen” signs exists there to the same (or a lesser or greater) degree than it does in the productive classifier handshapes in children.

5. General discussion and conclusions

Let us now return to the questions we asked in the introduction. We asked if these patterns are robust across sign languages and truly different from that of local gestures, and we can answer that they are, in both adults and children. The signers phonologize both joint and finger group complexity differentially toward Handling and Object handshapes, maintaining a delicate balance between iconicity, ease of perception and production, and a balanced and predictive distribution. Importantly, we have found that adult NSL signers exhibit a pattern of higher finger group complexity in Object handshapes than in Handling handshapes, the same pattern found in adults who use LIS, CSL, and ASL—languages with much longer histories. In addition, we would argue that these properties are used to form phonological oppositions in signers, but not in gesturers, due to the lack of a double dissociation (division of labor) in gesture between joint and finger group complexity in Handling and Object handshapes.

We have found that there are some differences among the sign groups and gesture groups, and it is possible that culturally shared gestural properties that both signers and gesturers have access to form the basis of these cross-cultural differences in both gesture and sign language, discussed further in the following.

We also asked if these patterns are evident in child language and, if so, whether they are acquired before or after the corresponding morphological system is in place. We found that the phonological pattern of finger group complexity is acquired prior to the morphosyntactic one associated with agentive/nonagentive distinction.

We can now consider the implications of these findings for acquisition, variation, and the emergence of phonology. We summarize our findings in the schema in Figure 12, with joint complexity results on the left and finger group complexity on the right. The nested squares at the top schematize the adult findings, and the age effects are given below those.

The figure is divided into three parts separated by the gray horizontal bars. Starting with the top portion, we see two main findings: the main effect for handshape type—that Handling handshapes

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6In child signers of LIS these two dimensions cannot be pulled apart because Brentari et al. (2015) demonstrated that in the acquisition of LIS, the morphosyntactic, agentive-nonagentive opposition of Handling and Object handshapes appears between 3;11 and 6;01 (earlier than in ASL).
have more joint complexity and object handshapes have more finger group complexity—and the main effect for Type of System—gesture groups exhibit higher joint complexity and signers exhibit higher finger group complexity. Crucially, there is no overall difference of complexity between gesture and sign if the two handshape types and two types of complexity are collapsed; both groups produce equally complex handshapes of one form or another.

In the middle portion, which indicates interactions of handshape type and specific groups, we see that all groups (gesture and sign) produce higher joint complexity in Handling handshapes, while only the sign groups show higher finger group complexity in Object handshapes. The finger complexity finding replicates the finding in Brentari et al. (2012). In other words, once signers recognize that both Handling and Object handshapes offer different types of iconic possibilities and introduce “hand-as-object” iconicity, they differentially apply handshape features to each handshape type, produce higher finger group complexity overall, and significantly higher finger group complexity in Object than Handling handshapes, a pattern not observed among gesturers. This creates a division of labor in which high finger group complexity is associated with Object handshapes and then, in order not to exceed a threshold that would make handshapes too complex, has the effect of lowering their joint complexity in Handling handshapes with respect to the gesturers. These findings suggest that sign languages place a maximum on the overall handshape complexity for the language, likely in order to allow for efficiency in terms of perceptual contrast and ease of production, and therefore joint complexity decreases somewhat in order to avoid handshapes that are too complex to communicate rapidly and efficiently.

The middle portion of Figure 12 also shows specific differences among groups. The Nicaraguan and Italian adult gesture groups show higher joint complexity than the Chinese gesturers, and ASL and CSL sign groups show higher finger group complexity than LIS and NSL signers. In other words, the Nicaraguan and Italian sign and gesture groups pair up consistently with respect to differences, even if these differences are along different dimensions.

The two age effects are indicated in the bottom portion of Figure 12. First, the joint complexity pattern is already quite stable at this age and shows only a weak effect of age between child and adult gesturers in Nicaragua. Second, children’s finger complexity shows the same effect (but to a greater degree) of Type of System as the adult groups, whereby sign shows greater finger complexity than gesture.

<table>
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<th>Effects</th>
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<tbody>
<tr>
<td>All groups same pattern</td>
<td>For Italy, Handling &gt; Object</td>
<td>For all countries, Object &gt; Handling</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Country Interactions | Nicaragua, Italy > China | US, China > Italy, Nicaragua |

| Age Interactions | Nicaraguan Adults > Nicaraguan Children | Children show greater effect of Type of System (Sign > Gesture) than Adults |

Figure 12. Summary of findings for joint complexity (left) and finger group complexity (right).
We might therefore tentatively conclude that the shared joint pattern develops from interacting in
the world via action, similar to Marentette & Nicoladis (2011), while finger complexity pattern is due
to exposure to a sign language. Even though adults exhibit more finger complexity than children in
gesture when collapsed across handshape type and country, only groups exposed to a sign language
exhibit the sign language pattern.

5.1. When does a system become phonological?
In other work concerning the emergence of phonology in sign languages, Sandler et al. (2011)
have focused on the recently discovered, relatively isolated community of signers in Israel who
use what has come to be called Al-Sayyid Bedouin Sign Language (ABSL), which originated
approximately seventy-five years ago. There are two points relevant to our findings that are worth
comparing with theirs. The first point pertains to whether an emerging sign language can have
phonological structure. Since ABSL has neither minimal pairs nor the type of feature spreading
rules (assimilation) commonly found cross-linguistically in spoken languages, Sandler et al.
conclude it does not yet have phonology. They state, “ABSL might get along very well without
dual patterning [phonology], and, we argue, it does.” We are not proposing that finger complex-
ity necessarily serves as a criterion to establish whether a particular language or a particular
individual has or lacks a phonological system. We would agree that ultimately phonology must
demonstrate systematic behavior, preferably of several kinds—including minimal pairs and
phonological rules in the vocabulary of the language that are shared across a language community
but also including patterns such as the ones described here. We interpret the emergence of
systematic patterns in finger complexity as one of the first indications of phonological organiza-
tion. Our findings accord well with Ladd’s (2014) recent argument that phonology can be present
without duality of patterning; we argue as well that duality of patterning not be an acid test for a
phonological system. Instead, Handling and Object classes of handshape exhibit related organiza-
tion at the phonological and morphological levels demonstrating the beginnings of both compo-
nents of the grammar. Having the phonological pattern for selected fingers and joints facilitates
the ascription of forms to their morphological classes. Starting with the more familiar and lower
complexity forms, initial patterns of differentiation set the ecology for categorizing the more
complex and later acquired or later emerging forms. The redistribution of features across the two
types of handshapes is phonology at work.

The second point is that Sandler et al. (2011) argued that morphology precedes phonology in
ABSL because duality of patterning is not (yet) in evidence, while ABSL already shows a pattern of
morphological verb agreement using spatial devices (Sandler et al. 2005). Sandler et al. arrived at
their conclusions by looking at two very different phenomena—verb agreement on the one hand,
which involves movement and location, and the form of lexical items, which involves handshape, on
the other. We suggest that the work presented here is a better test case of the order of componential
acquisition because it addresses two handshape phenomena that are closely related. Accordingly, our
findings align more closely with those found for spoken language (MacWhinney 1978, Ravid &
Schiff 2009); namely that phonology precedes morphology.

5.2. Language variation
We found interesting cross-linguistic differences among the four sign languages in adults that are
worthy of further investigation. In terms of their finger group complexity, LIS and NSL appear to
exhibit similar patterns, and ASL and CSL appear to exhibit similar patterns, across multiple dimen-
sions, despite the fact that this grouping pairs historically unrelated sign languages together. In future
work we will explore the typological variation among these languages, following on Padden’s division of
sign languages into Object-preference and Handling-preference languages (Padden et al. 2013).
5.3. Language acquisition and emergence

Our examination of variation in finger complexity across handshape types in sign languages provides a window into the nature of the emergence of phonological systems. While it is clear that sign languages, even emerging ones, are not simply elaborated gesture systems that arise merely from use (Carrigan & Coppola 2016), the gestural roots of the phonological contrast we discuss here start with the iconic influences that underlie “hand-as-hand” and “hand-as-object” representations. We find that the determinants of the initial forms of signs differ from the forces that reshape and reorganize a system of signs over time. Consequently, the organizational principles of sign languages grow to be qualitatively different from those of gesture. Sign languages do not merely echo or exaggerate the patterns present in gesture systems.

Language learners are key to this process of reorganization. In order to learn language, children must be able to identify the basic elements within a complex structure. This analytical eye, focused on an arbitrary arrangement, can detect seams where previously there were none. Thus learners create new elements as they learn. In the process of acquisition and emergence, signers (starting in childhood) become sensitive to a distinction between Object and Handling handshapes, and they begin to apply patterns of finger complexity that differentiate the two handshape types in a particular way. None of the gesture groups from which the signs apparently originate show this division of labor between the two handshape types. Yet they were evident already in a very young sign language, and in the signing of some young children who, in the meaning of their utterances, may not yet even mark the same contrast consistently. As more distinctions arise, new mappings can be realized, paving the way for more complex patterns to appear. And as each new generation learns the language, a phonology emerges.

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References


van der Hulst, Harry (see Hulst)