**Iconicity and biomechanics in the historical reconstruction of sign languages: A case study of the movement parameter in the Old LSF family**

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Sign languages seem not to be amenable to traditional historical reconstruction via the comparative method, making it difficult to replicate the successes achieved in the diachronic study of spoken languages. We propose to alleviate this difficulty with an alternative approach that draws upon both iconicity and biomechanics, especially the drive for reducing articulatory effort. We offer a preliminary, and necessarily speculative, demonstration of this approach with an analysis of the movement parameter in the signs for ATTENTION in French Sign Language and languages related to it. We show how consideration of iconicity and biomechanically natural changes can be enough to reconstruct a plausible movement parameter for the source sign and to explain the historical development of its modern descendants, even those that are superficially dissimilar. This method confirms known relationships and adds new evidence in support of suspected relationships, helping to fill in a methodological gap in the diachronic study of sign languages.

**Keywords:** sign languages; historical change; comparative reconstruction; articulatory effort; iconicity

## 1 Introduction

Comparative reconstruction has long been a successful enterprise for spoken languages. However, the same historical tools used for the analysis of spoken languages have not had the same successes for sign languages, for a variety of reasons, including their higher degree of iconicity. We propose a partial solution to these problems with an alternative approach that takes iconicity as an important part of the analysis, rather than an obstacle. In addition, given the significant differences in articulatory masses between spoken and sign languages, we also crucially draw upon biomechanical principles, with reduction of articulatory effort playing a central role. We explore how to combine these concerns for both iconicity and biomechanics to aid in the comparative reconstruction of source signs for a family of languages. As a case study, we offer a preliminary historical analysis of the movement parameter in the signs for ATTENTION in French Sign Language (*langue des signes française*, LSF) and other languages which are known or suspected to be derived from an older form of LSF, forming what we call the Old LSF family.[1] By considering both iconicity and biomechanics, we can reconstruct a plausible form of attention for Old LSF from which the modern signs in the family can be derived through expected articulatory changes. Our method explains all of the observed differences in the modern forms, confirms known membership in the Old LSF family, and adds evidence in support of other suspected members.

[1] In the sign language literature, we find a range of ways of referring to earlier stages of sign languages. Frishberg (1975) talks about "Old French Sign Language", and contrasts "old forms" to "modern forms" for American Sign Language. Supalla (2004) talks about data from "early ASL" in contrast to data from "modern ASL". Woodward (2011) talks about "original" sign languages, such as "Original Costa Rican Sign". Fischer (2015) compares "old" versions of signs to "current" versions and mentions "older ASL". Further, sign scholars will often compare the signs of "older" signers to those of "younger" signers when talking about diachronic change (as in McCaskill et al. 2011). We opt here to use the term "old" which seems to have the most general use in historical work on sign languages and which we treat as roughly comparable to the prefix "proto-" standardly used for historical reconstruction in work on spoken languages.

We begin in Section 2 with a review of the background of the diachronic study of sign languages. We also discuss the movement parameter in sign languages, the key articulatory property of interest in our study. We explain what it is, why we choose to focus on it, and what predictions we make about how it is expected to change over time. In Section 3, we describe the source and nature of the data set we are working with, which comes from the Spreadthesign database. Then in Section 4, we provide historical background on the languages of interest in the Old LSF family. The core of our analysis is given in Section 5, where we detail the reconstruction of the lexical item ATTENTION in the Old LSF family, demonstrating the mechanics of how our proposed methods work, helping to confirm the known constituency of Old LSF, and offering suggestive evidence for certain other speculated members of the family. We summarize our key results in Section 6, discussing the consequences of our analysis and offering suggestions for future work of this type.

## 2 Historical change and the movement parameter

In this section, we discuss some of the problems with attempting historical analysis of sign languages, with a focus on the role of iconicity (Section 2.1). We then discuss the movement parameter, which is the focus of our study (Section 2.2), offering predictions for the types of biomechanically natural changes we expect to find in the movement parameter (Section 2.3).

### *2.1 Issues in the historical study of sign languages*

Despite more than forty years of research, fundamental questions persist in studying the historical development and relationships of sign languages. While sign languages undergo many of the same kinds of diachronic changes that spoken languages do and are subject to comparable issues of language politics that aim toward standardization (Pfau & Steinbach 2006), determining genetic relatedness among sign languages is not straightforward (Padden 2011; Woodward 2011). For most sign languages, there is little to no available data from earlier periods. A notable exception is American Sign Language (ASL) (Long 1910; Supalla 2001; 2004), and ongoing longitudinal work is being done on other languages, such as Portuguese Sign Language of the Azores (Moita et al. 2018) and Nicaraguan Sign Language (Matt Dye, personal communication, September 2018). Further, for many sign languages, we do not have enough contemporary data to do reliable comparative or internal reconstruction (but see the SIGN-HUB research project, a four-year project funded by the European Union's Horizon 2020 Research and Innovation Programme; SIGN-HUB is collecting data from six sign languages, including data from elderly signers, which promises to be an important source for apparent time analysis of diachronic change in these languages; Bailey et al. 1991). It is thus not surprising that there are often conflicting analyses in the literature.

To complicate matters, although sign language communities do not often come into contact with each other, influence from contact is still significant. The first school for the deaf in a given country is often established by bringing in teachers from a school for the deaf in another country, and because that school then tends to serve as the parent school for the national sign language, the resultant language contact is more pervasive than the kind normally associated with trade interaction; the contact permeates the language. In these settings, the language(s) used by the instructors mixes with the varieties of signing that the students bring, so much so that certain sign languages may be best analyzed as creoles, as is sometimes argued for ASL (as in Woodward 1978; but see thorough critique in Kegl 2008).

Additionally, the issue of iconicity complicates crosslinguistic comparative study of sign languages, given its high incidence at both the lexical and sublexical level (Pizzuto et al. 1995; Pietrandrea & Russo 2007; Lepic et al. 2016; Wilcox & Occhino 2016). We follow Perniss and colleagues (2010) in viewing lexical items as iconic if they exhibit regular correspondences between form and meaning motivated by experience with the real world. Many signs originate as highly iconic, often using metaphor as the base for the iconicity (Wilcox 2000; Taub 2001; Meir 2010) or deriving from cross-modal linked mappings (Napoli 2017), so that unrelated languages which have had little or no contact might still have the same or similar signs for a given meaning. Of course, iconicity is not absolute; it can vary arbitrarily across languages, even those that are genetically related, such as ASL and Italian Sign Language (*lingua dei segni italiana*, LIS), which can have very different iconic signs for the same concept. For example, TREE and DANCE are both signed with whole-entity classifiers in ASL, but in LIS, TREE is signed with an outline-perimeter classifier, while DANCE is signed with embodiment.[2] Which properties of the real world are used as the base for a sign can vary so much that it can be difficult to recognize the iconicity involved in the articulation of the sign without knowing its meaning. Further, a sign's iconic origins can be lost when it becomes part of an organized linguistic system (Verhoef et al. 2016), so not only may unrelated languages appear related due to shared iconicity, true genetically shared iconicity may also be obscured. Thus, neither the presence nor absence of shared iconicity can be relied upon for determining shared history.

Such problems could theoretically be mitigated by something akin to the Neogrammarian hypothesis of regularity in sound change (Leskien 1876: xxviii; Osthoff & Brugman 1878: xiii), which has long been an important and powerful tool in the historical analysis of spoken languages. However, it does not seem applicable to sign languages (Moser 1990). Of course, spoken languages do not actually change in a perfectly regular way (see Labov 1981 for an overview), but the difference between modalities is still stark. For example, in the development of modern English, the Middle English long high front vowel /i:/ generally diphthongized to /aɪ/ in all words as part of the Great Vowel Shift (Luick 1896; Jespersen 1909), but we do not see analogous cases of regular phonological change in sign languages, such as the B-handshape changing to the 5-handshape in all signs, or all two-handed signs becoming one-handed, or all signs articulated on the forehead changing location to the cheek.

We suggest that the apparent lack of such regular phonological change in sign languages is due to their high degree of iconicity. This strong iconicity gives sign languages a tighter link between form and meaning than that found in spoken languages. Since semantic change is well-known for being largely sporadic rather than regular (Lehrer 1985: 283; Hock 2003: 456), this sporadic characteristic may be transmitted to the phonology via their tight iconic link, so that the inherent resistance of regular change in the semantics is shared with the phonology in sign languages (cf. Taub 2001: 229). This is supported by how phonological change in spoken languages similarly resists regularity when there is a tight iconic link to the semantics, as with onomatopoeia and other expressive or mimetic lexical items (see Mithun 1982 for numerous examples and references). Jespersen's (1922: 288, 406) classic example is the modern English word *peep* 'chirp', which should be pronounced with the same vowel as its cognate *pipe* 'flute; tube' due to the Great Vowel Shift. However, the /i/ of *peep* better retains the iconic sound of a baby bird chirping than /aɪ/ does, so the onomatopoetic use of the original word resisted the regular phonological change that altered its pronunciation it in its other uses. We propose that

[2] For ease of cross-linguistic comparison, we use English glosses in small capitals when referring to signs. Extra disambiguating information is provided when necessary.

this same principle is at work in sign languages, just to a greater degree due to the more extensive use of iconicity, to the point that regular phonological change is blocked in sign languages completely, so that only sporadic phonological change can occur.

Alternatively, it is possible that sign languages do in fact undergo some sort of regular phonological change for some appropriate phonological unit (i.e. the sign language analogue of the spoken language segment), which would mean that sign language phonology is not yet understood well enough for us to know what that may be. However, such a unit may not even exist (Wilbur & Petersen 1997), which would explain why it has not yet been found. Regardless, we cannot rely on Neogrammarian regularity, so our ability to conduct historical reconstruction on sign languages is necessarily limited.

### *2.2 The movement parameter*

In spite of the difficulties faced by historical work on sign languages, many linguists have forged ahead (as in the pioneering work of Frishberg 1975 and Woodward 1978). In particular, the apparent lack of Neogrammarian regularity necessitates looking for broad tendencies in similarity to support claims of historical relatedness among sign languages. To that end, it is generally assumed that the appropriate degree of similarity involves comparison of the distinctive manual phonological parameters, which include (at most): handshape, location, orientation, and movement (although some argue orientation is a feature of handshape; see Sandler 1989). McKee & Kennedy (2000: 48) propose that two signs count as related only if they differ by at most one parameter, though this may be too strict, since true cognates in spoken languages can show wide variation in both form and meaning. For example, Armenian *սար* (*sar*) ‘mountain’, Greek *καρότο* (*karóto*) ‘carrot’, Lithuanian *širšė* ‘hornet’, and Old Norse *hreinn* ‘reindeer’ are not superficially similar in form or meaning, but they are cognates that all ultimately derive from the Proto-Indo-European root **ḱer-* ‘head, horn’ (Pokorny 1959: 574–577; Mallory & Adams 2006: 137; Watkins 2011: 41–42).

The movement parameter has been reported by signers to be the most salient parameter for recognizing signs, either alone for non-native signers or in combination with other parameters for native signers (Corina & Hildebrandt 2002; Corina & Knapp 2006; Dye & Shih 2006; Orfanidou et al. 2009), thus understanding how movement changes is critical to any historical study of sign languages, and it is the main object of our study here. We show that recognizing sameness in movement requires recognition of plausible changes to a hypothetical source that may be quite different from the modern forms and that may obscure similarity across related languages (as with *սար* (*sar*), *καρότο (karóto)*, *širšė*, and *hreinn*). Specifically, we show that the movement parameters of cognate signs can look quite dissimilar until one takes into account the full history of the proposed older form and subsequent changes. However, without being able to rely on regularity of change, reconstructing older forms and changes for sign languages is more difficult and less reliable than it is for spoken languages.

The movement parameter is complex, at minimum involving direction of movement, shape of path, iteration, size of path, and speed. Of these, we focus primarily on the first two properties, because they are distinctive and unpredictable, while the others rarely distinguish a minimal pair that is not morphologically related (for iteration in particular, see Berent et al. 2014). The other three involve differences in articulatory effort, which is relevant to a discussion of the role of biomechanics in diachronic change. However, it is difficult to measure effort differences based on size of path, and speed, while it is easy for iteration: moving along a path multiple times requires that multiple amount of effort more compared to moving along that path

once. For this reason, we also take iteration into account. For our purposes, iteration requires repeated movement in the same direction; thus, moving forward and then backward along the same path is not iteration, just a return movement, but moving forward, then backward, and then forward again would be iteration (where the backward movement is considered a transition between the two forward movements; see Wilbur 2005).

There are two types of movement based on joint articulation: primary and secondary. Primary movement involves articulation of the shoulder and/or elbow joint, causing the entire hand to trace a route through space or on the body. Primary movement is often called path movement, and the route it traces is called a path. Secondary movement involves only the other joints of the manual limb (radioulnar, wrist, base knuckles, and/or interphalangeal knuckles) and does not cause the entire hand to trace a path. Nevertheless, secondary movement can cause most of the hand to trace a route through space. For example, in the ASL sign BOUNCE, articulated with a 5-handshape and wrist flexion and extension, the fingers and palm (but not the wrist) trace a visually salient arc through space. The important distinction between the two types of movement is that primary movement always involves the entire hand, including the wrist, moving along a path, while secondary movement always keeps at least the wrist in a fixed location (though it might rotate in place due to radioulnar articulation).

### *2.3 Predicted historical changes to the movement parameter*

Research over the past forty years has brought to light a number of processes that affect the articulatory shape of sign languages (see Napoli et al. 2014 for an overview), especially with respect to the movement parameter, most often for articulatory ease by reducing mass, acceleration, or distance traveled. Here, we catalogue some of those processes as the list of predicted types of changes in (1)–(9), which can be used to work backwards for historical reconstruction of older forms.

(1) *Iteration Loss*: Repeated movement along a path in a given direction is reduced to a single movement in that direction to reduce distance traveled and acceleration forces from direction changes, as found in lexicalization of compounds (Liddell & Johnson 1986; Corina & Sandler 1993; Wilbur 2017).

(2) *Weak Drop*: A two-handed sign with reflexively symmetric movement across the midsagittal plane changes to a one-handed sign by not using the nondominant hand at all (Frishberg 1975; Padden & Perlmutter 1987; Zimmer 2000), to reduce the total amount of moving mass (Napoli et al. 2014).

(3) *Weak Freeze*: A two-handed sign with reflexively symmetric movement changes to a two-handed sign with only one hand moving by keeping the nondominant hand in a fixed position (Padden & Perlmutter 1987; Mak & Tang 2011) to reduce the total amount of moving mass (Napoli et al. 2014).

(4) *Joint Freeze*: One or more joints are subtracted from the articulation of a sign to reduce the total amount of moving mass, with the shoulder and elbow being particularly prone to Joint Freeze (Meier et al. 2008; Napoli et al. 2014).

(5) *Joint Graft*: One or more joints are added to the articulation of a sign, usually the radioulnar or wrist in conjunction with Joint Freeze of a more proximal joint to maintain the overall visual shape of the path (Mirus et al. 2001; Crasborn & van der Kooij 2003; Meier et al. 2008; Napoli et al. 2014).

(6) *Torque Reduction*: Movement changes to avoid incidental torso twisting or rocking to reduce the reactive effort needed to maintain a stable torso, with twisting being particularly more unstable than rocking (Sanders & Napoli 2016a; b).

(7) *Lowering*: The location at which a sign is articulated is lowered to reduce the lift needed in raising the hands to a higher location (Tyrone & Mauk 2010).

(8) *Location Undershoot*: Movement to a target location is cut short to reduce the distance traveled, and thus, the effort (Brentari & Poizner 1994; Poizner et al. 2000; Mauk 2003).

(9) *Midsagittal Symmetry*: Other types of symmetry give way to reflexive symmetry across the unmarked midsagittal plane to reduce cognitive effort of muscle coordination (Frishberg 1975; Napoli & Wu 2003) and perhaps also to ease perception (Mechsner et al. 2001; Ferrara & Napoli forthcoming).

All of these predicted types of changes are based on the biomechanical drive for ease of articulation except Joint Graft (5). If articulatory ease were the only factor in diachronic change in sign languages, we would expect that all sign languages would change over time to make use of an increasing number of one-handed signs with minimal movement. However, the drive for articulatory ease is tempered both by a drive to maintain perceptual distinctiveness, as in spoken languages, and by the pressure to iconically align form and meaning (see Napoli 2017 for an overview of the evidence for this pressure). Instead, our point here is that focusing primarily on effort, with particular attention to joints and axes of movement, is potentially useful for confirming historical relationships between languages via comparative reconstruction. We demonstrate this point with data from an online corpus representing nearly forty languages.

**3 The Spreadthesign database**

Spreadthesign (STS; https://www.spreadthesign.com/) is a large database of signs maintained by the European Sign Language Centre in Örebro, Sweden. STS began in 2006 and continues to expand, currently containing over 432,000 total videos from 38 sign languages (as of 15 April 2019), mostly from sign languages of Europe, though other regions are also represented. We selected STS as our source of data for this study because it is the largest available corpus of multiple sign languages that we know of, and we believe the methods, as described to us by the STS coordinator, Thomas Lydell-Olsen (personal communication, December 2016), to be sound. Lydell-Olsen works with local partners in each participating country, and these partners translate the desired database entries from English into the local spoken language and then ask signers to present the corresponding signs. Some of the partners are deaf, and some of the hearing partners have training in linguistics and/or interpreting and have extensive experience working with deaf people, so it is not necessary for the signers themselves to be literate, nor are the signers subject to influence from the spoken language or its written form during elicitation. An administrator checks all entries for quality. STS is an extraordinarily useful trove of crosslinguistic data, often

including variants, phrases, and whole sentences, and we applaud all the many people involved with its establishment, growth, and administration. The present study, as well as recent large-scale crosslinguistic studies like Sanders & Napoli (2016b), Östling et al. (2018), Sanders (2018), and Yu et al. (2018), would have been significantly more difficult to undertake without STS. That said, there are still various limitations to the STS database which we note here.

First, not all of the languages are represented for each entry, with some being particularly underrepresented, so that complete comparisons are not always possible. However, most of the languages are robustly represented, so while it is difficult to directly compare every language in the database by looking at only a single entry, a patchwork analysis can be formed by comparing overlapping groups of a dozen or more languages for multiple entries.

Further, STS's method of gathering data by translating words from English into the local spoken language introduces the confounding factor of ambiguity and polysemy specific to English. For example, in the STS entry for ARGUMENT, some sign languages, such as Japanese Sign Language (*Nihon Shuwa* (日本手話), have a sign that corresponds to the meaning 'reasoning; justification', while others, such as Croatian Sign Language (*Hrvatski znakovni jezik*), instead have a sign corresponding to the meaning 'debate; discussion'. This can present issues when meaning is at stake, as in trying to determine the historical relationship between two languages based on presumed cognates. Such confusion is part of a larger issue: STS, like many sign language databases, is not a properly lemmatized dictionary (Johnston & Schembri 1999; see also Fenlon et al. 2015 for discussion of methods for lemmatizing BSL SignBank).

In addition, some signers seem to have personal tics or incomplete understanding of what meaning was being solicited. For example, one signer for Romanian Sign Language (*limbaj mimico-gestual românesc*) often fingerspells, as in the signs for the entries CRUMBLE, TEMPTATION, and VENGEANCE. Signers of several languages also seem to mime rather than sign for some entries that are particularly open to mime, with exaggerated movements outside ordinary signing space, as in many languages' signs for the entries SWIM and BASEBALL. Often, a signer gives a long phrase or even a sentence, perhaps because they do not know the specialized sign or no such sign exists, as in the signs for the entry CONFRONT in Bulgarian Sign Language (*bălgarski žestomimičen ezik* (*български жестомимичен език*)), POKE in Polish Sign Language (*Polski Język Migowy*), and VENGEANCE in LIS.

Finally, some signs may be based on cultural information particular to the country, which could prove inscrutable to an outsider without specialized knowledge. For example, some signs are based on emblematic gestures that can accompany speech or are used independently of language in the particular country, and thus may seem anomalous when compared to signs from other countries for the same entry. This is true for the sign for the entry JOKE in LIS: the gesture the sign is based on is commonly known as *cornuto*, the I-1-handshape, which looks like two horns, indicating that someone is being cuckolded. Of course, this and some of the other problems we note can be pitfalls with any linguistic elicitation, so these are not necessarily issues confined solely to STS or even to sign languages.

## 4 The Old French Sign Language family

Of the languages in STS, there is robust historical and synchronic evidence that some of them belong to the same families. One such family is the Old LSF family, which contains LSF, LIS, ASL, Brazilian Sign Language (*língua brasileira de sinais*, Libras), and Mexican Sign Language (*lengua de señas mexicana*, LSM). We propose that four other languages in STS, Spanish Sign Language (*lengua de signos española*, LSE), Chilean Sign Language (*Lengua de Señas Chilena*,

LSCh), and Indo-Pakistani Sign Language (IPSL) as used in India (notated here as IPSL-I) and in Pakistan (IPSL-P) might also belong to the Old LSF family, though the historical evidence is weaker. Our proposed Old LSF family tree, and its overlap with the Old British Sign Language (Old BSL) family, is given in Figure 1, with solid lines indicating firmly established relationships, dotted lines indicating weaker conjectured relationships, and parentheses indicating modern languages that are either not in the direct lineage of Old LSF (i.e. BSL) or not in the STS corpus (ISL), and thus, are not relevant to the current study.

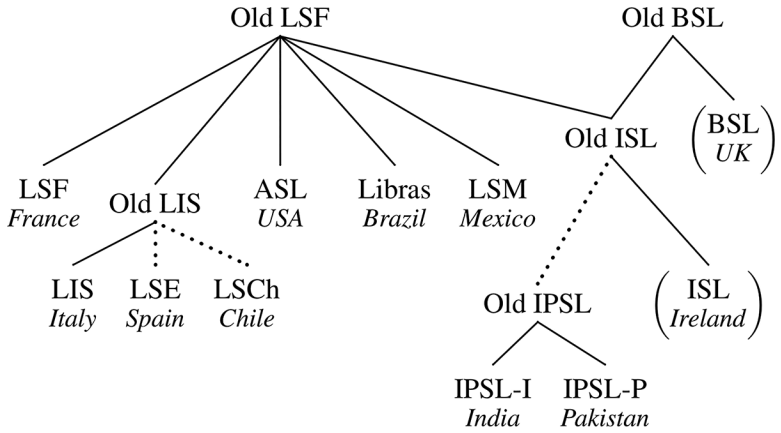


**Figure 1:** The Old LSF family, with possible inclusion of LSE, LSCh, IPSL-I, and IPSL-P.

In this section, we briefly discuss known historical information about these nine languages in the Old LSF family. We begin with the five languages in STS firmly established to be in the family and then propose four further related languages where we believe there is sufficiently reliable evidence to do so. We base our familial classification on available research that presents information that allows for a reasonable expectation of particular genetic relationships or for contact that is strong enough that one language may plausibly be profoundly impacted by another. We conclude with discussion of some tenuous proposals about genetic relationships that we do not adopt here.

### *4.1 French Sign Language (***langue des signes française*, *LSF)***

The world's first free school for the deaf, l'Institution Nationale des Sourds-Muets (later renamed l'Institut National de Jeunes Sourds de Paris, or INJS Paris) was founded in 1760 in France by Charles-Michel de l'Épée, the priest known in the literature as the Abbé de l'Épée. a Abbé de l'Epée invented a system of methodical signing, influenced by the signing of a largely silent sect of Cistercian monks (Cagle 2010) and the syntax of French. This signed French played a role in the formation of Old LSF (Lane 1980). The school's success led to many of its teachers fanning out to help establish similar schools in other countries (Berthier 1852), resulting in the development of many new sign languages at least partially derived from Old LSF.

### *4.2 Italian Sign Language (***lingua dei segni italiana*, *LIS)***

Italy's first school for the deaf, the Istituto Statale dei Sordi, was established by another abbot, Tommaso Silvestri, in 1784 in Rome. Silvestri was sent by a Roman lawyer moved by the plight of the deaf to INJS Paris in order to learn how to educate the deaf. After six months, Silvestri brought LSF with him to Italy, resulting in heavy influence from LSF on LIS (Radutzky 1992;

Corazza 1994; Pinna et al. 1994), although he also emphasized the importance of lip-reading, which Italian readily lends itself to (Volterra & Bates 1989) (Silvestri's methods are perhaps the origin of the prevalence of mouthing in LIS today (Ajello et al. 1997; Roccaforte 2018), although mouthing is still a foreign influence rather than a core component of the grammar (Giustolisi et al. 2017)). Education primarily in sign continued in Italy until the 1880 Milan Conference.

### *4.3 American Sign Language (ASL)*

In 1816, Laurent Clerc (another teacher trained at INJS Paris) was recruited by the American minister Thomas Hopkins Gallaudet to help establish the first successful school for the deaf in the United States, the Connecticut Asylum for the Education of Deaf and Dumb Persons (later renamed to the American School for the Deaf). The students were gathered from various northern towns and cities, including New York and Philadelphia (Tabak 2006), as well as from the Massachusetts island of Martha's Vineyard, where the deaf community was thriving and had developed a robust sign language. Thus, ASL may be analyzed as a creole based on LSF (from Clerc's teaching) and Martha's Vineyard Sign Language, which Groce (1985) hypothesizes may itself have itself been influenced by a sign language of Kent, England, where many of the residents' ancestors had originated from, though Kitzel's (2014) extensive study of the relevant historical records finds no evidence of a sign language in Kent, let alone that it travelled to Martha's Vineyard.

### *4.4 Brazilian Sign Language (***língua brasileira de sinais***, Libras)*

In Brazil, Ernest[3] Huet, a deaf educator also trained at INJS Paris, helped establish the first school for the deaf in Rio de Janeiro in 1857 (Noberto et al. 2014). Huet arrived in Brazil in 1855, so he had two years of exposure to the deaf community there before he began teaching in the school (Campos de Abreu 1994). Nevertheless, it is likely that Huet used LSF (Quadros & Campello 2010; Ramsey & Quinto-Pozos 2010) mixed with varieties of signing brought by the students. Confirmation comes from Campello (2011), who studied the first dictionary of Libras, Gama's (1875) collection of lithographs (Sofiato 2011), and found that LSF was integrated into an already existing indigenous sign language of Brazil.

### *4.5 Mexican Sign Language (***lengua de señas mexicana***, LSM)*

Huet was later invited by the president of Mexico in 1865 to come to Mexico City and establish a school for the deaf there (Jullian Montañez 2001). It was first housed in the Convento de San Juan de Letrán, but then opened as the Escuela Nacional de Sordomudos in 1867. LSM thus had initial influence from LSF (Ramsey & Quinto-Pozos 2010), which may still be noticeable today (Currie 1999; Currie et al. 2002; Hendriks & Dufoe 2014). Beyond that, ASL might have also had some influence on LSM in some border towns near Mexico (Quinto-Pozos 2006).

### *4.6 Proposed member: Spanish Sign Language (***lengua de signos española***, LSE)*

The first public school for the deaf in Spain was founded in Barcelona in 1800 by Joan Albert i Martí, with the help of the Jesuit scholar Lorenzo Hervás y Panduro (Quer et al. 2010). Though Hervás had visited the school for the deaf in Rome and had been influenced by the teaching method there, we have found no information suggesting that he learned LIS. The first private

[3] Or perhaps Édouard. Sources vary in what Huet's given name is and how his name is spelled (Bentes & Hayashi 2016: 858, fn. 3). There is speculation that Ernest and Édouard were twin brothers working in different countries (Ernest in Brazil, Édouard in Mexico), but there is little evidence to support this (Cruz Aldrete 2008: 8, fn. 21).

school had opened in 1775 and was converted into an institute for the deaf in 1805, and we also know very little about methods in that school. Despite being the original home of oralism in the mid-16th century (Gascón Ricao & Storch de Gracia y Asensio 2004; 2011), Spain has a long history of recognition of signing, with various private educational initiatives for the deaf (Plann 1997), so it seems likely that the signing used in the Barcelona school was based on what the children brought with them from home. Thus, we include LSE as only a possible member of the Old LSF family via potential but unconfirmed influence from Old LIS.

### *4.7 Proposed member: Chilean Sign Language (***Lengua de Señas Chilena*, *LSCh)***

Founded in 1852 in Santiago, Chile, the Escuela de Sordo-Mudos (now called the Escuela de Niños Sordos Anne Sullivan) was the first school for the deaf in Latin America, and its first director was Eliseo Schieroni, who had been a teacher for the deaf in Milan (Herrera et al. 2009; Herrera 2010). Given Schieroni's experience in Italy, there is a strong possibility that LIS provided an early influence on the development of LSCh, though we could find no direct evidence in the literature. Furthermore, following the recommendations of the 1880 Milan Conference, early deaf education in Chile was strictly oral, until the last half of the 20th century, with the introduction of the bimodal Total Communication method in some schools and the 1998 founding of the Escuela Especial Dr. Jorge Otte Gabler, the first LSCh-Spanish bilingual school (Puente et al. 2006; Herrera et al. 2009; Lissi et al. 2012). However, resistance to moving away from oralism still remains (Herrera et al. 2009). The lack of direct historical evidence for LIS influencing LSCh, combined with a long oralist tradition in Chile, leads us to posit LSCh as only a possible member of the Old LSF family, via potential but unconfirmed influence from Old LIS.

### *4.8 Proposed members: Indo-Pakistani Sign Language (IPSL-I and IPSL-P)*

The sign languages of India and Pakistan are represented separately in STS, but they are related (Woodward 1993), being argued to have only lexical differences, thus these languages might best be treated as regional dialects of IPSL (Zeshan 2000). We presume then that they derive from some older single source language, which we call Old IPSL. Though Zeshan (2003: 157) states that "IPSL is not known to be related to other sign languages of either Asia or Europe", we consider the possibility that the IPSL dialects may belong to both the Old LSF and Old BSL families, via a connection between Old IPSL and Irish Sign Language (ISL), which itself was originally influenced by BSL (via teachers of the deaf) and later by LSF (via nuns from Dublin visiting Paris to learn how to teach deaf students) (Burns 1998; Woll et al. 2001; Adam 2012).

The first school for the deaf in India was founded in Bombay in 1885 (Desai 1930: 141), but a few other schools were founded within the next couple of decades, including one in Calcutta in 1895 by Jamini Nath Banerji (Stevens 1923). It is clear from early writings that pockets of deaf people in India had been using sign languages for centuries (Dennis 2005). In the deaf school in Bombay, a number of Irish nuns and brothers were instructors, and they were accustomed to teaching in ISL. Thus, ISL likely mixed with the varieties of indigenous sign languages that the students brought to the Indian schools (McBurney 2012), and due to ISL's mixed history, we therefore have a potential second-generation link connecting the dialects of IPSL to both Old LSF and Old BSL.

### *4.9 Other conjectured relationships not pursued here*

We know of no confirmed genetic relationship of LSF to any of the other languages in the STS corpus. Conjectures about other possible relationships between sign languages abound in

encyclopedias and large-scale typological work (such as Wittmann 1991 and earlier editions of Ethnologue (Simons & Fennig 2019)). In particular, it is common for LSF to be claimed as an influence on many sign languages, but a close look at the historical situations casts doubt on those claims. We have pursued every thread to the best of our abilities and remain unconvinced by claims concerning relationships between LSF and other languages in STS not covered in 4.1–4.8.

For example, some claim that Austrian Sign Language (*Österreichische Gebärdensprache*, ÖGS) was influenced by LSF (Wittmann 1991). The first school for the deaf in Austria, the Taubstummeninstitut, was established in 1779 in Vienna (Dotter & Okorn 2003; Bickford 2005), leading to the development of ÖGS. The school used a mixture of signing and oralism developed by Joseph May and Michöl Venus, but this mixed method was abandoned with the advent of the Austro-Hungarian Empire in 1867 (Dotter & Okorn 2003). Though the Taubstummeninstitut was inspired by Emperor Joseph II's visit to INJS Paris, where he later sent May and Friedrich Stork to study the methods used there (Schalber 2015), we know of no evidence that LSF itself was used in the Taubstummeninstitut.

Likewise, some claim that Russian Sign Language (*russkij žestovyj jazyk* (*русский жестовый язык*), RŽJ) was influenced by LSF (e.g. Fischer 2015: 446). The first school for the deaf in Russia was founded in Pavlovsk in 1806 and moved to Saint Petersburg in 1810 (Williams 1993; Kimmelman 2014). While one of the first teachers at the Russian school, Jean-Baptiste Jauffret, was trained in Paris, he knew little sign language (Williams & Fyodorova 1993). If Jauffret's lack of signing was typical of the early teachers, this would be a key difference from the situation with LSCh, and there would be no opportunity for LSF to influence the development of RŽJ, especially in the face of the long oralist tradition persisting in Russia until bilingualism in the classroom emerged in the 1990s (Pursglove & Komarova 2003). However, the available information on the early period of deaf education in Russia is slim, so we do not dismiss the possibility of a relationship between RŽJ and LSF out of hand, though Bickford (2005) finds no evidence to support such a relationship.

Note also that the Old LSF family includes languages that we do not analyze in Section 5, either because they are not in the STS database (such as Quebec Sign Language; Carbin 1996) or because they are in the database, but STS lacks a video for our target sign ATTENTION (as for LSM and LSCh).

## 5 Exemplification of our method for ATTENTION in the Old LSF family

In this section, we compare how ATTENTION is signed across the languages in our proposed Old LSF family. In our description of the signs, we focus on the movement parameter, which we divide into three main components: joint articulation, axes of movement (appropriately extended from Sanders & Napoli (2016a; b) to include one-handed signs, as discussed below), and iteration. We treat these components as the atomic primitives of movement for the purposes of comparative reconstruction, somewhat analogous to place or manner of articulation in spoken languages. For example, given the cognates *brother* (English), *frāter* (Latin), *bhrā́tar* (Sanskrit), and *pracar* (Tocharian A) (Adams 2013: 455), it is reasonable to reconstruct some sort of labial obstruent at the beginning of the proto-word for 'brother', since the initial consonant in all four descendant cognates is a labial obstruent. Similarly, if a set of cognate signs all have articulation of certain joints in common, it is reasonable to reconstruct articulation of those joints in the source sign.

We do not attempt to account for all articulatory details here. Our goal is to show the potential benefits of a biomechanical approach to the historical development of the movement parameter specifically, though this may sometimes entail looking at other components of a sign, which we discuss when relevant. Because we are looking at broad patterns and not strictly regular correspondences, we consider all signs equally in our reconstructions, even though some sign languages are more closely related to others within their family.

Our choice of ATTENTION as our comparison item warrants discussion. In particular, this sign lends itself to an iconic representation, and, in fact, is iconic in many languages in STS. As noted in Section 2.1, while this could lead to accidental similarity, when a group of languages pattern together for multiple different signs, using the same iconic bases when a variety of possible iconic representations are available, we can be more secure in positing a familial relationship. Further, working with signs more prone to iconic representation makes it easier to reconstruct a hypothetical source sign, under the assumption that it would have likely been highly iconic. Of course, further work along the lines presented here would need to use a larger set of comparison signs across a range of possible iconicity types.

An interesting result of pursuing the discussion of iconic signs with respect to biomechanical principles is that we are offering an additional explanation (see Zeshan 2015 and Napoli 2017 for others) for why signers of one language often catch on to another sign language more quickly than speakers of one language to another spoken language: signers are used to applying biomechanical principles to reduce effort in their daily conversation, and given the higher degree of iconicity in sign languages than in spoken languages, signers may be able to mentally undo that effort reduction to recognize the underlying iconic sources, much as we are presenting here in the analysis of the Old LSF family's signs for ATTENTION.

### *5.1 The signs for ATTENTION*

The Old LSF family potentially contains nine languages from STS, including IPSL-I and IPSL-P from overlap with the Old BSL family. Six of those languages have one sign for ATTENTION in STS, and one language, IPSL-P, has two variant signs which we treat separately (notated here with subscript 1 and 2 on the language name: IPSL-$P_1$ and IPSL-$P_2$), for a total of eight signs in the analysis (LSM and LSCh are not represented). Note that the Libras sign is no longer on STS as of July 2018, but we had downloaded and analyzed the video when it was there in spring 2016, so we include it for completeness, though its inclusion or exclusion does not impact the analysis. Although all eight signs are different, six of them (LIS, ASL, Libras, LSE, IPSL-I, and IPSL-$P_2$) have notable similarities (exemplified here by the sign from LSE in Figure 2), with an easily imagined common source.

**Figure 2:** The LSE sign for ATTENTION (video available on STS at https://media.spreadthesign.com/video/mp4/5/18629.mp4).

The remaining two, the LSF sign (Figure 3) and the IPSL-$P_1$ sign (Figure 4), may initially look different from the other six, but careful consideration of the relevant biomechanics and the individual components of movement allows us to reconstruct a likely common source for all eight signs.

**Figure 3:** The LSF sign for ATTENTION (video available on STS at https://media.spreadthesign.com/video/mp4/10/18623.mp4).

**Figure 4:** The IPSL-$P_1$ sign for ATTENTION (video available on STS at https://media.spreadthesign.com/video/mp4/40/423049.mp4).

***5.2 Comparison of non-movement components***

Six signs use two hands with movement that is reflexively symmetrical across the midsagittal plane (hereafter 2HRM), while the signs from LIS and IPSL-$P_1$ use one hand (hereafter 1H). All eight signs have an initial location in the general vicinity of the eyes, with the signs from LSF and Libras articulated below the eyes, the sign from IPSL-I articulated above and to the outside of the eyes, and the remaining five articulated at the outsides of the eyes; all eight move forward to a final location in space in front of the face or neck not far from the initial location.

Five of the signs use the B or flat-B-handshape (which we conflate here as simply B-handshape) and have the palms oriented contralaterally (CL) and fingers oriented up (U); two of these (IPSL-I and IPSL-$P_2$) change the finger orientation from up to away (U>A) by elbow extension plus slight ulnar flexion at the wrist, as shown in Figure 5 for IPSL-$P_2$.

**Figure 5:** The IPSL-$P_2$ sign for ATTENTION (video available on STS at https://media.spreadthesign.com/video/mp4/40/429725.mp4).

LSF uses an upward-pointing 1-handshape initially facing towards (T) the speaker, and then slightly rotates the hands to face almost contralaterally while converting the handshape into a bent-1, keeping the finger orientation up. Note that we follow the literature (see especially Wilber 1979) in treating finger orientation as the direction in which the hand-internal finger bones (the metacarpals) point, that is, the direction the back of the hand points from wrist to base knuckles; thus, the handshape change in LSF does not alter finger orientation, which remains up throughout. Libras and IPSL-$P_1$ use a V-handshape; in Libras, the palm faces away (A) from the speaker with the fingers oriented up, while in IPSL-$P_1$, the palms face towards the speaker with contralateral finger orientation. These components of the eight signs are summarized in Table 1.

**Table 1:** Non-movement components of the signs for ATTENTION in the Old LSF family. sym = symmetry type, loc = location, hs = handshape, p-orient = palm orientation, f-orient = finger orientation

| | LSF France | LIS Italy | ASL USA | Libras Brazil | LSE Spain | IPSL-I India | IPSL-$P_1$ Pakistan | IPSL-$P_2$ Pakistan |
|---|---|---|---|---|---|---|---|---|
| sym | 2HRM | 1H | 2HRM | 2HRM | 2HRM | 2HRM | 1H | 2HRM |
| loc | eyes (below) | eyes (sides) | eyes (sides) | eyes (below) | eyes (sides) | eyes (above, sides) | eyes (sides) | eyes (sides) |
| hs | 1>bent-1 | B | B | V | B | B | V | B |
| p-orient | T>CL | CL | CL | A | CL | CL | T | CL |
| f-orient | U | U | U | U | U | U>A | CL | U>A |

Given these non-movement components, if these eight signs all came from the same source, it was almost certainly a 2HRM sign (with LIS and IPSL-$P_1$ undergoing Weak Drop (2)) articulated near the eyes (probably at the sides). The original source sign probably also involved the B-handshape, with the palms oriented contralaterally and the fingers oriented up. Thus, the signs from ASL and LSE may be the most conservative with respect to non-movement components.

### *5.3 Comparison of the movement parameter*

With respect to joint articulation, all eight signs involve elbow movement (el). The LSF sign also involves slight shoulder movement (sh) as the arms bounce, slight radioulnar twisting (ru) as the

hands rotate to face each other, and interphalangeal movement (ip) due to the handshape change. The IPSL-I sign involves shoulder movement, and like IPSL-$P_2$, also wrist movement (wr) as the finger orientation changes from up to away. This pattern of joint articulation is summarized in Table 2, with each joint listed in a dedicated row for ease of comparison across languages and "-" indicating that no articulation of that joint is used in the given language's sign.

**Table 2:** Joint articulation in the signs for ATTENTION in the Old LSF family.

| LSF<br>France | LIS<br>Italy | ASL<br>USA | Libras<br>Brazil | LSE<br>Spain | IPSL-I<br>India | IPSL-$P_1$<br>Pakistan | IPSL-$P_2$<br>Pakistan |
|---|---|---|---|---|---|---|---|
| sh | - | - | - | - | sh | - | - |
| el | el | el | el | el | el | el | el |
| ru | - | - | - | - | - | - | - |
| - | - | - | - | - | wr | - | wr |
| ip | - | - | - | - | - | - | - |

For axes of movement, we adopt Sanders & Napoli's (2016a; b) notation, which describes the direction of primary movement with respect to the system of three axes in Figure 6: away-toward (AT), up-down (UD), and left-right (LR).

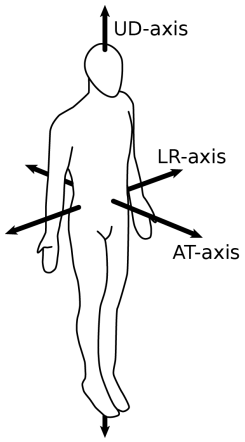


**Figure 6:** Three axes for describing path movement (Sanders & Napoli 2016a: 281).

For signs in which both hands move, we prefix the axis abbreviation with "+" if the hands move in the same direction along that axis or with "–" if the hands move in opposite directions; note that the hands may move in the same direction along one axis, in opposite directions along another, and not at all along the third, as in the ASL sign TRIANGLE, which traces the shape of a triangle in front of the signer, moving both hands down (thus, +UD) and moving one right when the other moves left (–LR), with no AT-movement. We extend this notation to accommodate signs in which only one hand moves along an axis, using the prefix "•" to mark such movement.

In all six 2HRM signs, the hands move away from the signer together, resulting in +AT movement. Additionally, in LSF, IPSL-I, and IPSL-$P_2$, there is notable downward movement of both hands along the UD-axis (+UD), and in the IPSL-I sign, the hands additionally begin by moving ipsilaterally away from each other along the LR-axis (–LR movement). The two one-handed signs, from LIS and IPSL-$P_1$, move the hand away from the signer along the AT-axis

(•AT), with the IPSL-P1 sign also moving the hand slightly downward along the UD-axis (•UD). These axes of movement are summarized in Table 3; as in Table 2, each row corresponds to one axis across all languages, and "-" indicates that no movement occurs along that axis for the sign in the given language.

**Table 3:** Axes of movement in the signs for ATTENTION in the Old LSF family.

| LSF<br>France | LIS<br>Italy | ASL<br>America | Libras<br>Brazil | LSE<br>Spain | IPSL-I<br>India | IPSL-$P_1$<br>Pakistan | IPSL-$P_2$<br>Pakistan |
|---|---|---|---|---|---|---|---|
| +AT | •AT | +AT | +AT | +AT | +AT | •AT | +AT |
| +UD | - | - | - | - | +UD | •UD | +UD |
| - | - | - | - | - | –LR | - | - |

Finally, in terms of iteration, there are two signs with true iteration (two iterations in ASL and three in LIS; we conflate all iterations and notate them simply as "I"), four with no iteration at all (LSE, IPSL-I, IPSL-$P_1$, IPSL-$P_2$), and two with small bounces at the end of the path (LSF, Libras). This slight bounce is not distinctive for Libras according to Rachel Sutton-Spence and Ronice Quadros de Muller (personal communication, May 2016). We take these bounces as a likely indication of original iteration cut short, which we notate as "(I)". The iteration component of these signs is summarized in Table 4.

**Table 4:** Iteration in the signs for ATTENTION in the Old LSF family.

| LSF<br>France | LIS<br>Italy | ASL<br>America | Libras<br>Brazil | LSE<br>Spain | IPSL-I<br>India | IPSL-$P_1$<br>Pakistan | IPSL-$P_2$<br>Pakistan |
|---|---|---|---|---|---|---|---|
| (I) | I | I | (I) | - | - | - | - |

In Table 5, we present all three of the movement components from Tables 2–4 together for ease of comparison, and we also offer our proposed reconstruction for these components in Old LSF, which we justify in the Section 5.4.

**Table 5:** Components of the movement parameter in the signs for ATTENTION in the Old LSF family, with proposed reconstruction for Old LSF.

| | LSF<br>France | LIS<br>Italy | ASL<br>America | Libras<br>Brazil | LSE<br>Spain | IPSL-I<br>India | IPSL-$P_1$<br>Pakistan | IPSL-$P_2$<br>Pakistan | Old<br>LSF |
|---|---|---|---|---|---|---|---|---|---|
| joints | sh | - | - | - | - | sh | - | - | - |
| | el | el | el | el | el | el | el | el | el |
| | ru | - | - | - | - | - | - | - | - |
| | - | - | - | - | - | wr | - | wr | - |
| | ip | - | - | - | - | - | - | - | - |
| axes | +AT | •AT | +AT | +AT | +AT | +AT | •AT | +AT | +AT |
| | +UD | - | - | - | - | +UD | •UD | +UD | - |
| | - | - | - | - | - | –LR | - | - | - |
| iteration | (I) | I | I | (I) | - | - | - | - | I |

### *5.4 Preliminary reconstruction of the Old LSF sign for ATTENTION*

First, we note that the underlying iconicity of using the hands as blinders to block out peripheral vision and direct eye gaze is apparent in all the languages except LSF, so we take this to be the iconic base of the original Old LSF sign. There is no obvious alternative iconicity at play in LSF, so we derive the LSF articulation as erosion of iconicity from our reconstructed Old LSF sign via reduction of articulatory effort. Relying on increased iconicity in the past allows us to make informed choices about how to reconstruct the Old LSF sign.

Looking at iteration, we note that, from a biomechanical standpoint, Iteration Loss (1) is a more natural change than iterating a sign's movement, because Iteration Loss reduces the amount of articulatory effort by at least half, often more. In order for the reverse change to occur, something should be gained that would be worth the extra effort of retracing a path, such as preserving iconicity. Here, however, there is no clear reason why an iterated version of ATTENTION would be more iconic than an uniterated version (contrast this with a sign like CHAT, which is iterated in every example in STS, likely because chatting itself is an iterative activity and therefore prone to an iterative iconic representation). Thus, we propose that the source sign in Old LSF involved iteration and that Iteration Loss occurred completely in LSE, IPSL-I, IPSL-$P_1$, and IPSL-$P_2$, and partially in LSF and Libras, with LIS and ASL faithfully retaining iteration from the source sign.

Reconstructing original iteration helps in reconstructing the original joint articulation. All eight signs have articulation of the elbow, so it is trivial to reconstruct elbow articulation in Old LSF. We might be tempted to reconstruct shoulder articulation as well, because Joint Freeze (4) is much more common than Joint Graft (5), especially for the shoulder (cf. Napoli et al. 2014). However, this means that the source sign was not only iterated, but involved both shoulder and elbow articulation (presumably to keep the hands moving in a straight line along the AT-axis). This is difficult to do, and if the source ever had shoulder articulation, it was almost certainly lost very early and not retained in LSF or IPSL-I. Thus, we propose that the modern shoulder articulation in LSF and IPSL-I is an innovation, and that the lack of shoulder articulation in the other six languages is a retention from the source sign.

Similar arguments apply to the appearance of radioulnar articulation in LSF, which we also take to be an innovation. Alternatively, radioulnar articulation could be original, perhaps all the way from a toward to an away palm orientation, with every language but Libras stopping the rotation halfway to face contralaterally, and then every language but LSF undergoing Joint Freeze (4) of radioulnar articulation. We do not pursue this more complex analysis, both because a simpler one is available and because the matter of determining stopping point of the rotation raises difficult questions. It is also possible that the wrist articulation in IPSL-I and IPSL-$P_2$ was original, but again, with iteration, it is hard to articulate both joints (though not as difficult as iteratively articulating both the shoulder and elbow), so we tentatively reconstruct only elbow articulation for ATTENTION in Old LSF, with Joint Graft (5) in LSF, IPSL-I, and IPSL-$P_2$.

Finally, since we propose a 2HRM source sign, and all six 2HRM signs in the Old LSF family have +AT movement (and the 1H LIS and IPSL-$P_1$ signs have •AT movement), it is reasonable to propose +AT movement for the Old LSF source sign. The question is then whether the +UD and/or –LR movements of LSF, IPSL-I, and IPSL-$P_2$ are innovations or retentions. Here, torso stability can provide insight. As Sanders & Napoli (2016a; b) note, +AT movement induces a rocking torque on the torso which must be resisted by the reactive effort of activating muscles around the abdomen. However, this torque can be mitigated by moving the hands along other axes at the same time, changing the angle at which the forces act on the torso, and thus,

reducing the magnitude of the torque. Thus, the addition of +UD and/or –LR movement in LSF, IPSL-I, and IPSL-$P_2$ can be seen as an example of Torque Reduction (6).

Overall, we see a range of degrees of change in the modern languages, which is very much what we expect given studies of diachronic change on spoken languages. The ASL sign is exactly the same as our reconstructed Old LSF sign, and most of the other languages differ from the reconstructed sign in only a few components, in each case, in an expected way due to the drive for ease of articulation. The utter normalcy of LSE with respect to the other languages is, we believe, no accident. Although full analysis of other entries in STS is beyond the scope of this preliminary work, we find examples (such as COLOR (noun), LATE, and RESPONSIBLE) in which the LSE, IPSL-I, and/or IPSL-P signs are easily derivable from a single source along with several of the other languages in the Old LSF family, while some very different signs occur outside this family. We therefore tentatively suggest that LSE and Old IPSL are in the Old LSF family and that the dotted lines connecting them in Figure 1 should be solid.

**6 Summary and discussion**

By taking both iconicity and biomechanics into account while comparing components of the movement parameter in signs for ATTENTION, we have confirming evidence for the well-established membership of LSF, LIS, ASL, and Libras in the Old LSF family, as well as possible support for suggestions that LSE, IPSL-I, and IPSL-P might be in this family as well. This approach provides a preliminary but promising framework for reconstructing older forms of cognate signs and clarifying historical relationships between languages.

While some languages in STS outside the Old LSF family not analyzed here (such as those in the Old Russian Sign Language family) have very different signs for ATTENTION which seem to be derived from a different iconic source from our proposed reconstruction for Old LSF, there are other languages in STS whose signs for ATTENTION do have obvious similarities to those in the Old LSF family. This could be taken as evidence in support of some speculations in the literature concerning familial relationships not proposed here. However, where there is no historical relationship to the other languages, we do not believe that mere similarity is sufficient. Rather, the meaning ‘attention’ simply lends itself to being realized iconically in certain ways, one of which seems to be the iconic base for the Old LSF family, but easily could also have independently been the iconic base for other languages. This is an inherent problem to working with historical analysis of sign languages, which heavily rely on iconicity. Thus, consideration of the known historical evidence is crucial, as is looking at a wide range of signs when considering more speculative family relationships.

Note also that what counts as the “same” iconic source may not be superficially obvious, as with the LSF sign in comparison to the rest of the Old LSF family. With sufficient change over time, the original source may be obscured so that true cognate signs may not be recognizable as such. This is a problem shared with spoken languages, but it is not as easily mitigated. With spoken languages, we can rely on the regularity of sound change to fill in gaps in the historical record, but this seems not to be available for sign languages. Thus, we have to rely more heavily on other principles to help reconstruct the past. In the approach proposed here, the two primary principles at work are iconicity and biomechanics.

A direct consequence of considering the interplay between iconicity and biomechanics is the central importance of the movement parameter, with location, handshape, and palm and finger orientation being peripheral concerns. We assume that earlier forms of a sign will tend to be more iconic and use more articulatory effort (perhaps dating from a time when the sign

language was newly arising in an educational setting, where hyperarticulated citation would be widespread), while later forms will tend to be less iconic and use less articulatory effort (as generations of signers introduce more natural fluidity and efficiency to how signs are articulated). Of course, this is just a general trend, so any particular case may contradict this, but as a guiding principle, it seems useful for structuring a general method for historical reconstruction in sign languages. This general trend toward reduction of articulatory effort would show up most prominently in the movement parameter (especially path movement due to the larger masses being moved by shoulder and elbow articulation; Napoli et al. 2014). Changes in the other parameters may also be driven by articulatory effort reduction, but the articulatory savings will generally be much smaller, so perceptual concerns may weight more heavily. Thus, as a starting point for considering biomechanics, the movement parameter is an obvious choice.

We are also proposing that iconicity itself is an explanation for why sign languages do not appear to be subject to Neogrammarian regularity, and thus, why iconicity holds such a prominent place in our analysis. The inherent resistance to regular change in semantics can be spread to the phonology where iconicity is sufficiently pervasive: in sign languages generally and in some domains of spoken languages, such as onomatopoeia. This proposal could be interpreted as suggesting that non-iconic signs may be subject to regular change. This would be difficult to test, since it is hard to argue that a given sign did not originate via iconicity, since iconicity may apply not only to visual representations that physically resemble what they mean, but also to those that somehow evoke what they mean is some more abstract way. This second category of iconicity is "motivated" (in the sense of Russo 2004; Perniss et al. 2010), perhaps through some culture-based metaphor (Adam et al. 2007; Meir 2010) or perhaps through some physiological (often somatosensory) cross-modal chain (in the sense of Napoli 2017). Regardless, even if non-iconic signs could be neatly categorized separately from iconic signs, their numbers may be so small that there would be no meaningful difference between regular change and sporadic change in a few lexical items, especially since phonological change often diffuses through the lexicon, rather than behaving categorically regular (Labov 1981). We leave this question open, but we suspect that the pressures working against Neogrammarian regularity in sign languages are simply too great for it take root.

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**Competing Interests**
The authors have no competing interests to declare.

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