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Counting with fingers symbolically: basic numerals across sign languages.

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1 Introduction

Language acquisition, including number marking, appears to bootstrap the learning of numerals and calculation (Carey, 2009; Carey, 2004). It has been shown that cross-linguistic differences in number marking can influence number acquisition (Almoammer et al., 2013; Marušič et al., 2016), and during the initial stages of number acquisition, children use the same mechanism to acquire linguistic number (Barner, 2017).

There is experimental evidence that number gestures support counting acquisition as well by enhancing the understanding of one-to-one correspondence (Alibali & DiRusso, 1999; Gibson, Gunderson, Spaepen, Levine, & Goldin□Meadow, 2019), and may be learned even earlier than number words (Gunderson, Spaepen, Gibson, Goldin-Meadow, & Levine, 2015). Several accounts link the evolution of number concepts and number words to the availability of iconic elements that have stable order, such as fingers or other body tallies (Wiese, 2007). However, neither number gestures nor body tally systems of the world are universal. Number gestures differ significantly across cultures, but are highly conventional inside the same culture (Comrie, 2013; Pika, Nicoladis, & Marentette, 2009), which often makes them a shibboleth, as exemplified by Tarantino (2009).

Recent studies show that children may, in fact, be sensitive not to the iconicity of the number gestures, but to their conventionality (Nicoladis, Marentette, Pika, & Barbosa, 2018; Nicoladis, Pika, & Marentette, 2010), and the one-to-one mapping between the number of objects and the number of fingers may not be crucial. Still little is known about the acquisition of number gestures and their function in the acquisition of symbolic number, as well as the role of iconicity.

Number acquisition by deaf children using natural sign languages is even less studied (Leybaert & Van Cutsem, 2002a). Instead, researchers often focus on deaf children educated orally and often find that deaf school children lag behind their hearing peers in mathematics achievements (see Swanwick, Oddy, & Roper, 2005, for review). This delay may be related to educational methods and language deprivation: experimental studies suggest that initially, deaf preschoolers show sensitivity to number category, just as hearing children do (Zarfaty, Nunes, & Bryant, 2004). What happens next is yet to be discovered – but conventional manual counting experience influences counting strategies both in deaf and hearing adults (Domahs, Moeller, Huber, Willmes, & Nuerk, 2010; Klein, Moeller, Willmes, Nuerk, & Domahs, 2011) and thus may contribute in a particular way in acquisition of number concepts.

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Studies of number acquisition and sign languages can shed light on the role of iconicity in the acquisition of number: sign languages have rule-governed number systems (just as spoken languages do) that use manual articulators with possibilities for iconicity readily available (like number gestures).

As mentioned above, the number gestures used across cultures are highly variable. Bender & Beller (2011) provide the example that number 8 can be shown in at least seven ways. In this study, we attempt to compare the basic hand configurations used for numbers 1 – 10 in the sign languages across the world to see if their variability and distribution resembles those of number gestures.

The numeral symbols of sign languages are constrained by the physical properties of the manual articulators. Not all hand configurations are anatomically possible, but the list of possible strategies is extensive. At the same time, sign languages are governed not only by anatomic but also by linguistic, phonological constraints (Sandler, 2012). The number signs of sign languages also coexist with the numeral systems of spoken languages and the number gestures of hearing people. An important question is how sign language numeral systems differ. Several seminal works on number typology in sign languages have been published (Zeshan & Palfreyman, 2017) together with descriptions of numeral systems of individual sign languages (Fuentes, Massone, Fernanez-Viader, Makotrinsky, & Pulgarin, 2010; Morgan, 2013; Yang, 2016; Zeshan, Escobedo Delgado, Dikyuva, Sibaji, & De Vos, 2013) However, an analysis of the general properties of sign language numeral systems has not yet been done. This information is crucial for understanding the interconnections of number and language, taking into account studies of number gestures and their role in early number development.

1.1 Numeral systems of sign languages.

1.1.1. Iconicity

The numeral symbols of sign languages are constrained by the physical properties of the manual articulators, as we only have two hands, ten digits, the signing space has limits, and not all hand configurations are anatomically possible. This differentiates them from the extended body part numeral systems that may use the whole body with pointing (Bender & Beller, 2011; Comrie, 2013).

Natural sign languages of Deaf people in the world always exist in the situation of diglossia (with spoken languages), and sometimes their numeral systems do depend on the number gestures of the coexisting hearing culture (Morgan, 2017; Safar, Guen, Collí, & Hau, 2018), but in many cases it does not (Fuentes, Massone, Fernanez-Viader, Makotrinsky, & Pulgarin, 2010; Zeshan & Palfreyman, 2017).

One specific type of iconicity in sign languages is called *number-to-number* and is specific to number constructions. In such cases, numbers are represented by extending a corresponding number of fingers of the dominant hand (Taub, 2001). However, different languages rely on this strategy to varying degrees, and its utility is limited by a number of

naturally available articulators (10 fingers). Most sign languages in our database use this kind of iconicity for the sign numbers ONE to FIVE.

Another kind of iconicity that has been described in sign languages is orthographic: signs for numbers resemble the written forms of these numbers in a form conventional for their community. Examples include Arabic digits for Turkish Sign Language, Kanji for Japanese Sign Language numbers (Zeshan & Palfreyman, 2017) or spoken Russian number words for Russian Sign Language where the signs THOUSAND and MILLION in initialized, and their handshape refers to the first letter of the corresponding Russian word (Semushina & Mayberry, 2019).

Mediated iconicity that is not specific to numbers can be found in numeral systems as well. Morgan (2017) mentions that the sign for THOUSAND in Kenyan Sign Language bears a resemblance to a particular currency bill that was red and was used in 1960 when the first Deaf school was founded. This strategy has been found in spoken languages, as well (Greenberg, 1978). For instance, in many languages, the numeral 5 may be related to the lexeme for *hand* (Calude & Verkerk, 2016).

1.1.2. Numeral base (radix)

According to Calude & Verkerk (2016). The derivation of a compositional numeral in a language usually involves three components: atoms (already existing primary numerals), a base (an atom used serially to derive larger numerals), and an arithmetic operation, such as addition, subtraction, multiplication, division, or exponentiation[1]. This approach accounts for languages that have more than one base type (such as French). More importantly, different operations can have different bases which may be morphologically derived from existing atoms or be separate unrelated lexemes (which Fuentes & Tolchinsky (2004) call "operators"). According to Seiler, (1990), numeral bases share three fundamental properties. First, the bases are "turning points" on the number line where the linguistic rule for number formation changes. Second, irregularities in the derivation patterns of a given language tend to cluster around the base form. Finally, the choice among competing forms for representing the same number also tends to occur at the base.

The notion of the numeral base, or radix, in sign languages appears to be problematic (Zeshan et al., 2013). Although "base" is mostly defined as the value *n* such that numeral expressions are constructed according to the pattern ... $xn + y$, i.e., some numeral x multiplied by the base plus some other numeral (Comrie, 2013), although some sign language studies define base as those numerals based on which other numerals

[1] - For example, English number 84 (*eighty-four*) would have a structure of 8 x 10 + 4, where 8 is an atom, 10 is a base, and the operation is multiplication. In French, the same number (*quatre-vingt-quatre)* would have a structure 4 x 20 + 4, where the base is 20, and the atom is 4. In Russian Sign Language, 84 would have the same structure as in English.

are constructed (Lanesman, 2016; Zeshan et al., 2013). Several studies (Fuentes & Tolchinsky, 2004; Leybaert & Van Cutsem, 2002) leave the notion of the base undefined, which sometimes makes the evaluation of their analysis difficult. Several papers introduce the notion of sub-base; some do not.

Although most sign languages described to date are claimed to have decimal numeral systems, bases of sign language numeral systems do differ: ASL has a decimal numeral system; German Sign Language has a decimal system with a subbase of 5 (Pfau, Steinbach, & Wall, 2012), Algerian Jewish Sign Language has a quinary numeral system (Lanesman, 2016). Some shared sign languages have been reported to have bases higher than 10 (Zeshan et al. 2013). At the same time, there exists a disagreement among sign language scholars, concerning the languages with base and sub-base of 5, so for this study, we had to reevaluate several findings for the sake of terminological uniformity. When evaluating numeral bases of sign language numeral systems on the videos and in published data, we followed the definition of Calude & Verkerk (2016).

Most developed sign languages emerged together with deaf education, which means that their first deaf signers had access to schooling and spent considerable time in the school environment. It seems plausible that school curriculum included mathematics from the beginning, so sign language numeral systems evolved in close contact with written systems of number notations. This is reflected in the systems with orthographic iconicity (that we will discuss in the section 2.2 below). This may be a factor influencing the type of numeral bases that sign languages of deaf communities have. An overwhelming majority (80 0f 82) of the numeral systems in our data are decimal. However, two-handed numeral systems do have a sub-base of 5, as Roman numeral notation had (Chrisomalis, 2019), which is naturally available because of the properties of manual articulators. We consider 5 to be a sub-base because numerals 6 – 9 are formed from it by addition. However, we find two languages have quinary numeral systems: Algerian Jewish Sign Language (Lanesman, 2016) and Colombian Sign Language.

Sign languages typically use movement morphemes to express a range of numerals (1-10, 11-19, 20-90 etc). For example, in RSL 16, 60, 600, and 6 000 are derived from 6 and differ from it (and from each other) only in movement. Each operation (multiplication by 10, exponentiation) has its own pattern. The sign for 66 would be a combination of 60 and 6. This pattern is not universal across sign languages. For example, in ASL digits are also signed in the linear order, but round decade numbers (for example, 20) have a specific movement, while others are signed as a sequence of digits (23 is a combination of 2 and 3, and not 20 and 3). In German Sign Language the order is the inverse (and 23 is a combination of 3 and 20) (Pfau, Steinbach, & Woll, 2012).

Sign languages also use operators – separate lexical signs to express range or operation (Fuentes & Tolchinsky, 2004). For example, in Catalan Sign Language one way to sign 200 would be to use signs TWO and HUNDRED sequentially. Most sign languages make use of both simultaneous morphology and operators. The phonological constraints of particular languages define these constructions: for example, in RSL THREE_THOUSAND would be one sign with a handshape 3 and a specific movement,

while SIX THOUSAND is expressed sequentially, using THOUSAND as an operator after the numeral SIX.

1.1.3. Variation

All numeral systems, of signed and spoken languages, are reported to have several irregularities (Gvozdanović, 1999). For example, in ASL, while number 24 is signed as a combination of 2 and 4, "25" has a handshape of 5 and the middle finger moves up and down a few times (MacDougall, 2008). The irregularity may appear not only on a single number, but on part of a range. For instance, RSL has 2 ways to refer to the numerals 11-15, one-handed (with quick extension of the corresponding number of digits) (Semushina & Mayberry, in press.), and two-handed, where the non-dominant hand has a handshape from the sign for 10 and on the dominant hand the needed number of fingers is extended (Geilman, 2001). Besides that, there are differences in number articulation between Deaf and hard-of-hearing Russians.

McKee, McKee, and Major (2011) working on the young New Zealand Sign Language (NZSL), point out a high level of dialectal variation for the range from 1 to 20 across groups of NZSL signers as a function of age, gender, region, and ethnicity. This situation contrasts with most studied spoken languages, according to the authors. This might be related to the fact that NZSL has dialectal variants centered around five centers of Deaf education in New Zealand.

Sociolinguistic variation specific to the language emergence setting is observed in other sign languages too (Valli, 1989). For example, in Russia ,Deaf and Hard of Hearing students were historically educated in different schools (Basova & Yegorov, 1984), which results in the dialectal differences. In the USA, Deaf education was segregated for a long time, and a new dialect developed in the Black Deaf community (Mccaskill, Lucas, Bayley, & Hill, 2011). In Argentina, education for deaf boys and girls was separate for a long time, which also impacted the numeral systems used by women and men (Fuentes et al., 2010). Gendered education affected Irish Sign Language as well (Matthews, 1996).

1.2 Methodology and sources

As a source for our data, we used the online sign language dictionary spreadthesign.com, as well as multiple educational sign language videos published on the internet, coming mostly from sign language teaching projects or Deaf-owned vlogs.

Spreadthesign is an international project, initially created by the European Sign Language Center that currently unites sign language users and researchers from different countries and includes a multilingual sign language dictionary with an option of comparison for the same lexical item across many sign languages. Besides *spreadthesign*, we used dictionaries for ASL (American Sign Language), Costa Rican Sign Language, Greek Sign Language, Hungarian Sign Language, Israeli Sign Language, Swedish Sign Language, and Russian Sign Language available online.

If for a particular sign language, the linguistic analysis of the numeral system was available, we primarily relied on it. For other languages, we also used materials from educational and popular science *YouTube* channels, as well as Deaf vlogs, including the videos that explicitly compare different sign languages. For every language we tried to use as many videos as possible, to assure consistency across the sources. This was not always possible, however. The second author selected the video materials.

The limitations of our study relate to methodology. They include the impossibility of controlling for the signer's proficiency, the decontextualized nature of data, and difficulties controlling for dialectal or generational differences. Another limitation relates to language status and community identification. For example, based on the lexicographic materials and educational videos, sign languages of Post-soviet countries bear significant resemblance to Russian Sign Language, and are often considered dialectical, but research is needed to discover the degree of this. Based on the data available on *spreadthesign*, number signs for 1 – 10 are identical in Russian, Ukrainian, and Belorussian Sign languages, but we still consider them to be three separate languages, because that is how the Deaf communities of the three countries identify them.

Similarly, there are multiple sign languages in India described in the sign language literature (Woodward & De Santis, 1977): Nepali Sign, Bangalore Sign, Indo-Pakistani Sign Language. However, educational videos with different signs often are called "Indian Sign Language," which complicates classification and prompted us to exclude the video from the corpus.

Despite these challenges, the purpose of the following study was to give an overview of potential strategies that sign languages use to form basic numerals (atoms). We think that our method satisfies this goal of our project. The possibility of in-depth typological analysis of numeral systems across sign languages is currently limited by both the scarceness and quality of the available data, but we aspire to do this in the future.

2 One- and two-handed numeral systems

2.1 Two-handed numeral systems

2.1.1. Handshapes

As we have mentioned in the introduction, humans have two hands, a readily available tool to create a highly iconic ten-based numeral system, but not all sign languages use this tool. There is evidence that a system can move away from it. For example, the literature describes that at earlier stages of its development the emerging Nicaraguan Sign Language had a two-handed numeral system, which by 1990 rapidly changed into a one-handed system (Flaherty & Senghas, 2011). It is an open question whether there exist other pieces of evidences that number signs move away from transparent iconic patterns, as other lexical signs have been shown to do (Frishberg et al.,

1975), and that Deaf community sign languages with more extended history (like ASL) moved toward one-handed numeral systems?

Our survey included 82 sign languages around the world. Among them, 36 used two-handed numeral systems. Of these 36 languages, four are shared sign languages (Bengkala, Chicana, Algerian Jewish and Mardin Sign Languages), and all the others are sign languages of large deaf communities. The data on language emergence is not always available, but, if possible, we attempted to discover when the first deaf school was founded for every particular country (if available in the literature or on *Ethnologue*). Among languages that had these data available (17 total), 11 of the two-handed numeral systems emerged in the 19th century or before, ranging from 1791 (or earlier) for French Sign Language to 1886 for Croatian Sign Language. Three languages supposedly emerged in the 1st part of the 20th century (Venezuelan Sign Language, Uruguayan Sign Language, Israeli Sign Language), and three languages emerged after 1950 (Kenyan Sign Language, Tanzanian Sign Language, Ugandan Sign Language). Based on these data, it seems unlikely that two-handed numeral systems are linked to the age of language.

As shown in Figure 1, two major clusters can be seen: two-handed numeral systems in Central Europe and one-handed systems in Asia.

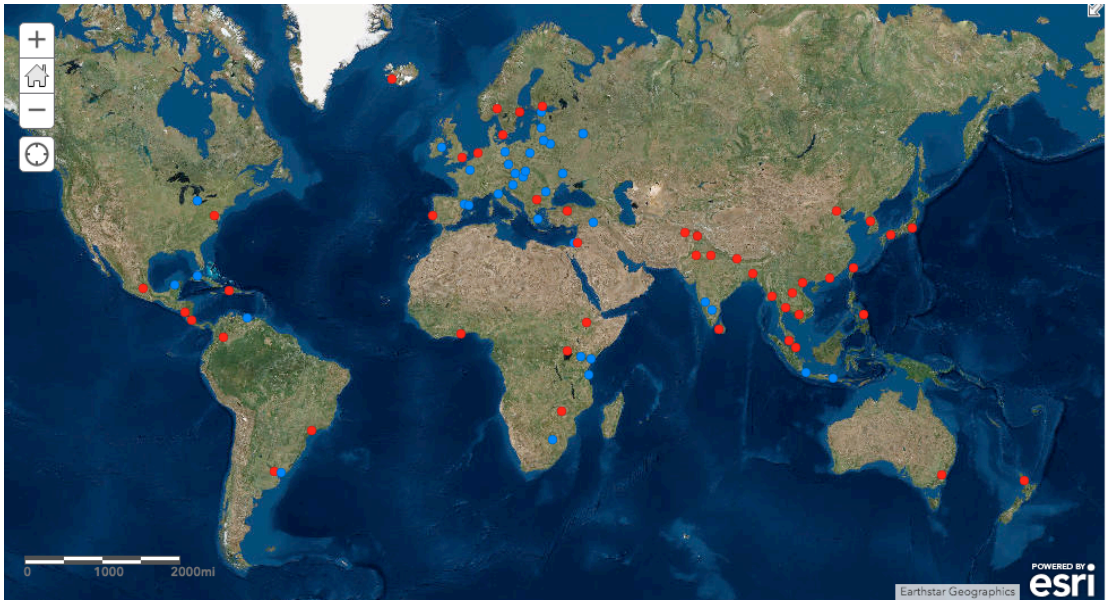

Figure 1. Geographic distribution of one- (red) and two-handed (blue) numeral systems across sign languages.

For the first five numerals all languages use extended fingers, making use of number-to-number iconicity (except for Algerian Jewish Sign language, that has a non-iconic handshape for 5). Two-handed numeral systems can be divided into two subgroups: those that include hand contact and those that do not.

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In most of the numeral systems with no contact (26 of 36,) the number 6 is expressed by the extension of five fingers on the non-dominant hand and one on the dominant hand. For the subsequent numerals, the necessary number of fingers on the non-dominant hand is extended, using the strategy of *number-to-number iconicity* (Taub, 2001).

Although languages that make use of this strategy are mainly clustered in Europe (Italian Sign Language, French Sign Language, German Sign Language, and others), such numeral systems also are found Asia (Bangalore Sign Language), and South America (Uruguayan Sign Language, Venezuelan Sign Language and others).

As far as the sociolinguistic situation and circumstances of language emergence are concerned, we find this pattern in sign languages of large Deaf communities (see Nyst, 2012, for terminological discussion), as well as in rural (or shared) sign languages (Zeshan et al., 2013).

Mardin Sign Language (Zeshan et al., 2013) has a very particular numeral system. The non-dominant hand only appears in the sign for 10 (all fingers simultaneously extended, number-to-number iconicity), but the numerals from one to nine are one-handed. Several numbers are expressed through the sequential combination of the sign 5 with other numbers (so that the sign that designates 5 is a compound FIVE^ONE). Thus, the system combines simultaneous and sequential ways to express number through finger extension. Sequential combinations also were attested in Chicano Sign Language, another sign language of shared community (Zeshan et al., 2013).

Among the ten sign languages that do have contact between two hands while articulating the numbers, there can be distinguished three patterns: contact with open palm, contact with fingers, and contact with the fist.

Russian Sign Language exemplifies the first pattern (Moroz 2015; Semushina 2015) the non-dominant hand with the handshape 6 is oriented palm out, and the dominant hand with corresponding handshape (1 for SIX, 2 for SEVEN) contacts it. This pattern can be observed not only in sign languages of the former USSR that are historically related to RSL (such as Ukrainian and Belorussian Sign Languages, but also in Tanzanian Sign Language. Tanzanian Sign Language emerged when the first school for the Deaf was established in 1963 (Lee, 2012) and is not historically related to RSL.

The second pattern is where the fingers of one hand contact the fingers of the other with both handshapes being different. This pattern was found in Irish Sign Language.

The third pattern was found in Rwandan and Kenyan Sign Languages (Morgan, 2017). There is no information available about Rwanda Sign Language history, but Kenyan Sign Language traces its history to 1962, when two Deaf schools were first opened in Kenya. While education was oralist, sign language emerged among the Deaf students. Unlike in the Nicaraguan school for the Deaf where Nicaraguan Sign Language originated, Kenyan schools were residential, where the children spent at least nine months of the year, which might have influenced the pace of language emergence. The KSL numeral system probably emerged from the gestures that hearing people in West Kenya (where the first schools were situated) used in the 1960s (Morgan, 2017).

The numbers from one to five are identical in these two languages (palm facing the signer, extended index finger for 1, extended index and middle fingers for 2, extended pinky, ring and middle fingers for 3, pinky + ring and middle + index in V-like form for 4, and fist for 5). For numbers after 5, KSL uses two-handed signs where the extended fingers of the dominant hand (with 1, 2, 3, or 4 handshapes) touch the fist (which is 5), and 10 is two fists contacting each other (Morgan 2013).

Rwandan Sign Language has a different strategy, using orthographic iconicity. For example, sign for 6 is the thumb extended facing up; 7 is thumb and index fingers extended facing down; the number 8 bears resemblance with the Arabic digit 8 (extended middle finger, contacted by curved thumb and index fingers), and 9 has an extended thumb facing down (the reversed 6). However, sign for 10 is the same as in KSL – two fists contact facing each other.

To sum up, in our data two-handed numeral systems in sign languages seem to rely a great deal on *number-to-number iconicity* (Taub, 2001) except for Rwandan Sign Language and partially Kenyan Sign Language. Despite the wide range of anatomically possible finger combinations and positions, most of the languages under consideration used one common strategy, namely finger extension, no contact between hands, with unmarked 5 handshape on the non-dominant hand in two-handed signs. Note that the consistency of the dominant hand handshape is valued more than handshape symmetry: although the number 8 could be represented symmetrically by extending four digits on each hand, in our data this construction it is not attested. Finally, the strategy that Russian and Tanzanian Sign Languages use also relies on *number-to-number iconicity*, but less transparently.

2.1.2. Variation: numeral systems with optional two-handedness

The numeral system of Catalan Sign Language was described as optionally two-handed. In this language, the number 8 may be signed both by two hands (5 handshape on the non-dominant, 3 handshape on the dominant hand, both palms facing out) or by one hand (dominant, with 3 handshape). In this case, signs for 3 and 8 are minimal pairs, differing in orientation, as well as pairs 4 and 9, or 2 and 7 (Fuentes et al., 2010).

Interestingly, a similar pattern can be observed, if we consider language change in Russian Sign Language (Semushina, 2015). As described in the previous paper, Russian Sign Language has a two-handed numeral system; numbers 6 – 9 are signed with two hands in contact, where sign for 6 is composed of a non-dominant hand 5 handshape, and a dominant hand with a 1 handshape. However, younger signers of RSL in the data collected for that project also produced one-handed versions of the numbers 6 – 9. In this case, as in Catalan Sign Language, the signs 1 – 5 become minimal pairs in orientation for signs 6 – 9.

Although several younger signers report using one-handed version as their default way to refer to numbers, older singers of Russian Sign Language reject this version as informal. They understand it, but do not accept it to be used in any formal context such as

public speaking or interpreting for someone who is not the signer's close friend or family (Semushina, 2015). For Catalan Sign Language, such a difference in the register is not reported, nor is the potential sources of variation. In Nicaraguan Sign Language, the one-handed numeral system replaced the older two-handed one. Flaherty & Senghas (2011) explain that the residual traits from original two-handed signs can still be observed in the new numeral system, although *number-to-number* iconicity is lost. The new number signs described in their paper also have specific movements that one-handed numerals did not have. It is not observed for RSL and LSC one-handed numerals: they differ from their two-handed counterparts by deletion of the non-dominant hand.

Argentinian Sign Language (LSA) also has two co-existing numeral systems, one- and two-handed, but they might be etymologically unrelated. The two-handed system, relying on number-to-number iconicity is only found in older women who went to a girls-only deaf school in Buenos Aires (Fuentes et al., 2010). The one-handed numeral system of LSA is not iconic at all.

In LSC and RSL two numeral systems seem to coexist, and so far the tendency towards replacing two hands with one has not been observed by researchers. In LSA the two-handed system is slowly disappearing together with its dialect. Thus, these data do not support the hypothesis that numeral systems evolve towards less iconic one-handed forms.

2.2 One-handed numeral systems

Forty-six sign languages in our data have one-handed numeral systems. If two-handed numeral systems cluster in central Europe, one-handed numeral systems are frequent in Asia and in North and South America. The distribution and frequency may be influenced by multiple factors, such as contact with number gestures of hearing cultures and other developed sign languages. For example, there might be an influence of ASL on local sign languages through the migration of American educators, as happened in Thailand (Woodward, 1996). Several other sign languages in our data have numeral systems identical to the one of ASL.

Just as for sign languages with two-handed numeral systems, sign languages with one-handed systems vary in respect to the date of their emergence (again, this estimate is based on the onset of deaf education, if available, in the literature or on *Ethnologue*). These dates are from approximately 1760 (British Sign Language), 1800 (Swedish Sign Language) to 1979-1980 (Cambodian Sign Language, Nicaraguan Sign Language), with 14 languages originating in 19th century, and 15 in 20th. Thus, the distribution of one-handed numeral systems based on their age also does not provide support to the hypothesis that older and more established sign languages evolve towards one-handed systems.

In our sample, there was only one shared sign language with a one-handed numeral system: Myuakubo Sign Language, signed on an isolated community in Japan (Yano & Matsuoka, 2018). This language has a very particular numeral system with signs for numbers 6 – 1 articulated on the signer’s cheek.

2.2.1 Orthographic iconicity

Sagara and Zeshan (2016) describe how the one-handed numeral systems of sign languages in many cases rely on orthographic iconicity. In our data, six sign languages have numeral systems that rely entirely on number-to-number iconicity for the numbers 1 – 5 and on orthographic iconicity for the numbers 6 – 9. Ugandan Sign Languages bases its numbers on Hindu-Arabic digits. Turkish Sign Language and Pakistani Sign Language base iconicity on Arabic-Indic numerals. Japanese Sign Language bases numerals on the Kanji hieroglyphic system. Chinese Sign Language relies on hieroglyphic system resemblance (Yang, 2016). Jordanian Sign Language numerals iconically resemble the Eastern Arabic Numerals that are currently used in conjunction with Arab alphabet. However, in many sign languages numeral systems rely on mixed strategies, combining iconicity of both types with arbitrary signs.

2.2.2 Mixed strategies

For some Arabic digits, iconic representation strategies are more readily available than for others. For example, the numbers 6 and 7 bear a resemblance to the Arabic digits in 11 sign languages, partially relying on orthographic iconicity, but this is not apparent for the number 8. At the same time, we must be cautious in judging potential iconicity: a handshape with thumb up for 6 and thumb and index extended for 7 could resemble corresponding Arabic digits, but they might also be a remnant of iconic two-handed signs, as in Nicaraguan Sign Language (Flaherty & Senghas, 2011), or be a part of some other strategy.

Some other numbers, such as 8, are rarely represented iconically. In our data, the sign for 8 is iconic only in Pakistani Sign Language, Jordanian Sign Language, Turkish Sign Language (which resembles the Indic Arabic digit), and Ugandan Sign Language (which resembles the standard Arabic digit), (*Ugandan Sign Language Manual For Families Good Samaritan School for the Deaf*) Among other languages, the most common strategy is to represent 8 by extending 3 fingers (the fingers vary between languages).

An example of a numeral system relying on multiple strategies is Australian Sign Language. The number 6 with an extended curved thumb is similar to the Arabic digit 6. However, Johnston (1989) note that the bent finger is a recent innovation. The extended curved thumb and index fingers (reversed L handshape) bear iconic similarity to the digit 7, but the number 8 with extended curved thumb, ring and middle fingers does not. The signs for 9 (5 handshape with bent pinky finger) and 10 (middle finger contacts the thumb, all other fingers extended) are not iconic either. Johnston (1989) notes that handshapes 7, 9, and 10 do not occur in other signs of Australian Sign Language. We may hypothesize that perceived iconicity of the sign for 6 might be a latter phenomenon, and the number signs 6 to 9 seem to follow a definite pattern with finger extension starting with the thumb.

Bulgarian Sign Language is similar. The numbers 1 – 5 are signed with palm out: 2 has middle and index fingers extended, 3 extends the index, middle, and ring fingers, for 4 all fingers are extended (but not the thumb), all demonstrating number-to-number iconicity. In this system, the number 6 (thumb up, palm facing out) may be perceived as being orthographically iconic. However, the numbers 7 – 9 are not, nor do they demonstrate number-to-number iconicity: the number 7 is formed through extension of thumb and index finger, for 8 the thumb, index, and middle finger are extended, 9 has the thumb and all the fingers extended except for the pinky finger which is bent, while 10 has a distinctive handshape with index and pinky fingers extended, while the other fingers form a fist with thumb on top of other fingers.

Thus, it is possible that in the numeral system of Bulgarian Sign Language (and Auslan) there coexist orthographic iconicity, number-to-number iconicity, and signs that cannot be interpreted as relying on iconicity, such as the numbers 7 – 9. For example, the signs 3 and 8 have the same orientation and the same number of fingers extended with the only difference being which fingers these are.

2.2.4 Limits of the iconicity

There are numeral systems that do not seem to rely on orthographic iconicity. Among them Argentinian Sign Language has two numeral systems (Johnson & Massone, 1992). The historical roots of this particularity can be found in the separate schooling for Deaf boys and Deaf girls in Argentina. The more typologically typical numeral system based on number-to-number iconicity supposedly emerged in the Deaf school for girls, but is used more rarely now. This was discussed above in the section 2.1.2.

The currently dominant Argentinian Sign Language numeral system comes from the schools for boys; this type of variation can be found in the domain of color and time (Fuentes et al., 2010). The dominant numeral system does not rely on any iconicity; it also extensively uses contact with body, neck, and face in different locations. These signs are not identifiable as numerals by a non-signer, and their meaning is not transparent. They do not seem to be derived from manual counting.

Argentinian Sign Language is one of the two numeral systems in our data that uses contact with the body. Another one is Miyakubo Sign Language, where number signs 1 to 5 are typically number-to-number iconic, while 6 – 10 are signed contacting the cheek (6 – index finger taps the cheek, 7 – index and middle, 10 – five fingers; alternatively, 10 is signed with two hands, palms open outwards (Yano & Matsuoka, 2018).

However, Argentinian Sign Language is unique, as it does not seem to rely on iconicity at all. All other sign languages in our data do rely on number-to-number iconicity for the first numbers on the number line. Surprisingly, the limits for this iconicity differ among languages.

Most of the languages in our sample make use of the natural possibility to express numbers from 1 to 5 through finger extension. However, some sign languages do not use it and iconic numbers end at 4, where the subitizing limit ends.

In Korean Sign Language, this iconicity ends at 4, and the sign for 5 is a fist with the palm facing outwards, as in A handshape in ASL (Domahs et al., 2012). The Korean sign SIX has thumb and index extended (and thus looks like the sign for 7 in many other sign languages). In Algerian Jewish Sign Language, the sign for number 5 also has a distinct handshape, a flat O handshape (Lanesman, 2016).

2.2.5 Handshape and movement contrasts in one-handed numeral systems

As we have discussed, in one-handed numerals the number of extended fingers often is predictive of the numerical value: three extended fingers can represent both 3 and 8, as in Australian, Bulgarian and other sign languages. To distinguish between the two interpretations, sign languages use different strategies.

The most frequent strategy is changing selected fingers: for example, in Finnish sign language numbers 1 – 5 are signed through extension of fingers starting with the index, while to sign 6, the pinky is extended, and then for subsequent numbers digits are added in the opposite direction (Takkinen, Jantunen, & Seilola, 2016.), and the sign for 10 is a thumbs up. Among the languages that also use the selected fingers to distinguish between, say, 3 vs. 8 and 5 vs. 9 are British Sign Language, Cambodian Sign Language, Dutch Sign Language, Nepali Sign Language, and Vietnamese Sign Language.

Interestingly, in some two-handed numeral systems, such as Russian Sign Language, the numbers 2 and 3 can be signed with different selected fingers (using the thumb or not). As soon as the number of fingers is three , it is interpreted as 3 (Semushina, 2015). However, in New Zealand Sign Language, variation is found inside a one-handed system, and differences with signs with three fingers extended (whether it represents 8 or 3) may depend on mouthing (McKee, McKee, & Major, 2011).

Another strategy is a change of orientation, where the signs for 3 and 8 will have the same selected fingers but would be minimal pairs by the palm facing either away or towards the signer. This strategy can be exemplified by the one-handed numerals of Catalan Sign Language (Fuentes & Tolchinsky, 2004). This strategy can be used for all numbers 6 – 10, or for some, as in Norwegian Sign Language (9 vs. 4, 8 vs. 3), and Dutch Sign Language (5 vs. 10).

In the introduction we explained that sign languages typically use movement morphemes to express a range of numerals (such as tens, thousands), but not numbers under 10. However, Colombian Sign Language does use internal movement to form the numerals 6 – 10. In this language, the sign ONE is an extended index finger, and the sign. SIX is an extended index finger that bends twice. We could not find the full paradigm, but movement morphemes also form the numbers (10 + *n*): a quick extension instead of bending. Swedish Sign Language and Nicaraguan Sign Language also have internal movement in basic numbers, but they do not seem to be morphemes for specific arithmetic operation, such as (5 + *n*) as in Colombian Sign Language.

3. Discussion

Overall our data show that numeral systems of the world's sign languages demonstrate many similarities to each other. Despite the wide variety of possibilities that the manual articulators and the human body in general offer, they use a limited number of strategies. Only two sign languages use a location other than the hands and neutral signing space: Argentinian Sign Language and Myuakubo Sign Language have signs that contact the head.

The data on sign language families is not always available, but languages attributed to the same family may have very different numeral systems. For example, Russian Sign Language and French Sign Language have two-handed numeral systems (that also differ from each other), and American Sign Language has a one-handed system. All three languages are attributed to Old French Sign Family (Frishberg et al., 1984.; Grenoble, 1992). However, there is a geographic clustering: numeral systems of the same type are likely to be neighboring. A similar phenomenon was observed in spoken languages (Comrie, 2013).

At the same time, even though the iconic strategy of fingers extension is available, not all languages use it. Most sign languages use one-handed numeral systems with a limited degree of transparency. Sometimes number signs bear iconic resemblance to a specific number notation, but most systems rely on that strategy only partially, if they at all.

The degree of iconicity present in sign language numeral systems also does not seem to correlate with sign language age and setting of emergence; the oldest developed sign languages known to date have both one- and two-handed numeral systems, and do not seem to "evolve" away from iconicity, although that tendency does exist for lexical signs (Frishberg et al., 1984). At the same time, while some languages have optionally two-handed systems, our data is limited and may not include such languages.

Clearly more research is required to include more sign languages. Nonetheless, we are confident that our principal result would still hold: sign languages use a limited number of similar mechanisms to form numeral systems, relying more on conventionality than on iconicity.

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