Title

A Representational Analysis of Numeration Systems in Sign Languages

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 48(0)

Authors

Anceschi, Chiara

Bender, Andrea

Publication Date

2026

A Representational Analysis of Numeration Systems in Sign Languages

Chiara Anceschi[1] & Andrea Bender[1, 2]
[1]Department of Psychosocial Science, University of Bergen
[2]SFF Centre for Early Sapiens Behaviour (SapienCE), University of Bergen

Abstract

Although highly relevant to questions on how numeration systems are shaped by format, sign languages have rarely been included in representational analyses. Our study addresses this gap by examining how systems in 63 typologically diverse sign languages represent numbers across the base and power dimensions. The analysis shows that, unlike other formats, sign languages frequently combine multiple representational strategies within their numeration systems. In the base dimension, the reconciling needs for transparency and articulatory economy causes shifts from cumulative to ciphered representations. In the power dimension, format-specific constraints guide which representational strategies remain viable, with parsed representations dominating higher powers. These findings highlight the important contribution that sign languages can make to comparative research on numeration systems and underscore the need for a more format-sensitive understanding of numerical representation.

Keywords: sign languages; numeration systems; number representation; embodied cognition; language evolution

Introduction

Numeration systems are paradigmatic examples of culturally evolved cognitive tools: They are invented, they get transmitted and modified across generations, and they evolve in response to cognitive and cultural pressures. A systematic comparison of how numbers are represented across modalities, formats, and cultural contexts can reveal the cognitive implications of these representations and help understand their evolution. The key tool for achieving this is *representational analysis* (Zhang & Norman, 1995), which allows us to examine how different manners of representing the same information affect cognitive processes. Whereas representational analyses have been carried out for numerical notations (Chrisomalis, 2004; Widom & Schlimm, 2012; Zhang & Norman, 1995), spoken languages (Bender et al., 2015), and body-based systems (Bender & Beller, 2012; Dudojć et al., 2025), sign languages have received little attention. Yet, because numeration systems in sign languages combine the bodily affordances of body-based systems with the structure of natural languages, overlooking them clearly hampers our understanding of how format influences numerical representation. Moreover, including sign languages into the picture may also provide insights into the influence of socio-cultural and developmental contexts on numerical representation, given the variation in how sign languages emerge and are used, which has been suggested to affect the structure and complexity of their numeration systems (De Vos & Pfau, 2015).

To address this gap, we have conducted the first representational analysis dedicated entirely to numeration systems in sign languages. We have focused specifically on dimensional representation, defined as how numerical information is represented on various dimensions in these systems, according to accounts of distributed cognition the property with the biggest impact on number processing (Zhang & Norman, 1995; Zhang & Wang, 2005).

We begin with a brief overview of the framework that guides our analysis and the steps taken in it, followed by a description of the dataset. We then present the key findings and discuss the patterns emerging for numeration systems in sign language in comparison to those in other modalities and formats.

Conceptual Framework

Numeration systems are means for representing numerical information, but not all do this in the same manner or even to the same extent (Bender & Beller, 2018). The first way in which they can differ is in the *format* through which numerical information is conveyed: through physical objects, as in material systems; through written numerals, as in notational systems; through number words, as in verbal systems; or through the body, as in body-based systems. Within this typology, numeration systems in sign languages occupy a particularly interesting place because, although they are produced through the body exactly like body-based systems, they are part of fully fledged natural languages and therefore parallel verbal systems in their linguistic structure and complexity.

Across these formats, numerical representations can encode different kinds of information, as demonstrated by Zhang and Norman in a seminal paper (1995): Nominal information indicates whether two numbers are identical; ordinal information indicates which of two numbers is larger; interval information indicates distances between numbers; and ratio information indicates their relative proportions. Crucially, numeration systems differ in the extent to which such information is made explicit versus remains implicit, and this difference in *representation* is critical for cognitive representation and number processing, as it affects cognitive load.

Another property that is central for understanding the cognitive implications of numeration systems is their *dimensionality*, which reflects how the system is internally

In G. Boleda, I. Dautriche, M. Maldonado, C. Saldana and T. Torrent (Eds.), *Proceedings of the 48th Annual Conference of the Cognitive Science Society*

structured. Numeration systems can be unstructured (or one-dimensional), such as tally marks, or they can be structured around one or more compositional anchors. A compositional anchor is a number to which compositional operations (addition, multiplication, subtraction, and division) are applied to form the composite numerals in a system (Pelland, 2025). When a compositional anchor is used to form most of the composite numerals in a system, it is referred to as a main anchor, and when a main anchor has exponential properties, it is referred to as a base (Pelland, 2025). In addition to main anchor or base, systems can also employ other anchors to form composite numerals. Such anchors, which are used less frequently than the main anchor or base, are called secondary anchors. Employing a compositional anchor increases the system's dimensions and makes it possible to express large numbers while keeping the system compact and cognitively manageable. Systems structured around a base or main anchor are two-dimensional, and systems that also employ a secondary anchor are three-dimensional.

The way in which numerical information is represented along a system's dimension(s) can vary substantially, and such variation plays a central role in how numbers are processed. Because this study focuses specifically on dimensional representation, we provide a more detailed account of this property below.

Dimensional representation

As mentioned before, how many dimensions a system possesses depends on whether or not it employs a compositional anchor. Unstructured systems, which lack any anchor, have only one dimension, the *base dimension*, while systems with a compositional anchor have, in addition to the base dimension, also a *power dimension* (Bender & Beller, 2012). Therefore, while in unstructured systems, the base dimension comprises all numerals in the system, in structured systems, it includes only the numerals up to the main anchor or base, which are then reused as addends and multipliers when forming composite numerals.

Numbers in the base dimension can be represented in a cumulative or a ciphered way[1] (Widom & Schlimm, 2012), and this has cognitive implications (Bender & Beller, 2018; Zhang & Norman, 1995): In *cumulative* representations, the same token is repeated as many times as required to represent the value of the numeral and reflecting one-to-one correspondence. Because the amount of tokens is proportional to the numerical value represented, cumulative representations explicate the full range of numerical information, facilitating counting and number processing. Conversely, in *ciphered* representations, a single representational token is used to represent a given number, thereby leaving three of the four types of numerical information implicit and consequently increasing the cognitive load of the system.

The second dimension assessed in dimensional representation, the *power dimension*, only exists in systems that are structured around a base or main anchor (and, if present, any secondary anchor[2]). It refers to how the value of the base and that of its multipliers are distributed among representational tokens. According to Widom and Schlimm (2012), the power dimension (referred to as "base representation" in their typology) can be represented in three ways, each with specific advantages and trade-offs, depending on the degree to which the power and multipliers are externally separable. In *integrated* representations, the same sign represents both the base raised to a given power and its multiplier; in *parsed* representations, one type of token represents the base at a specific power, while another represents the multiplier; and in *positional* representations, it is the position of the multiplier sign that indicates the power of the base with which it is multiplied.

Format-specific patterns

The framework outlined above originates in the work of Zhang and Norman (1995), where it was developed for the analysis of numerical notations. It was refined and elaborated on by Chrisomalis (2004; 2010; 2025) and Widom and Schlimm (2012), still for notational systems, and adapted to body-based systems by Bender and Beller (2012). The latter included two examples of sign language systems, German Sign Language (DGS) and American Sign Language (ASL), yet mainly for illustration of variability rather than as systematic survey. This shift in representational format, in which the systems under scrutiny were implemented, disclosed some challenges.

Most notational systems are regular and hence fall into one category, with their base dimension being either cumulative or ciphered, and their power dimension being either integrated, parsed, or positional. For example, Roman numerals fall into the cumulative-integrated category, while Western numerals[3] fall into the ciphered-positional one. Exceptions exist, but are rare. For example, in the Egyptian hieratic numerals, the representation of the base dimension is cumulative for 1 to 4 but ciphered for 5 to 9, and in the Greek alphabetic numerals, the representation of the power dimension is integrated below 1000 but parsed above it (Widom & Schlimm, 2012).

Matters are far less straight-forward for systems in other formats, and especially so for body-based representations,

[1] While the terminology is that of Chrisomalis (2010, 2025), "cumulative" and "ciphered" are used here in the sense proposed by Widom and Schlimm (2012), as they describe how numbers in the base dimension are represented (in their typology "the multiplier representation") and not how each exponent of the base is represented (intraexponential organization).

[2] It should be noted that in a system structured, for example, around a base of value-10 and a secondary anchor (here: sub-base) of value-5, although all numbers from 1 to 9 including 5 serve as multipliers, the representation of 5 itself should not be assessed in the base dimension, but in the power dimension, and 6 to 9 will most likely be composite numerals.

[3] Following Chrisomalis (2020), we adopt the term "Western numerals" instead of "Indo-Arabic numerals," as it more precisely captures their historical trajectory and current form.

including sign language systems such as ASL (Bender & Beller, 2012; Dudojć et al., 2025). In fact, many sign languages in our dataset (to be described below) employ diverging types of dimensional representation at various points in their numeration system and hence resist simple categorization.

Rather than undermining the usefulness of the approach, however, this highlights the need for further elaboration to enable more fine-grained examination. For instance, a more nuanced analysis of the base dimension that reveals which numbers are represented cumulatively and which in a ciphered manner, can inform us about the tension between articulatory economy and increased cognitive load. Likewise, an analysis of the power dimension for each power of the base separately can pinpoint where each system shifts to a new representational strategy and how those are distributed across powers, illustrating how sign languages negotiate the need to represent large values with that to keep the systems cognitively manageable.

The Dataset

The dataset for our analysis was compiled using data from existing resources identified through a targeted literature search. Relevant publications on numeration systems in sign languages included grammars, peer-reviewed articles, and doctoral dissertations. These source types were prioritized, but when they were unavailable for a given language, we also consulted dictionaries, digital repositories, and teaching materials.

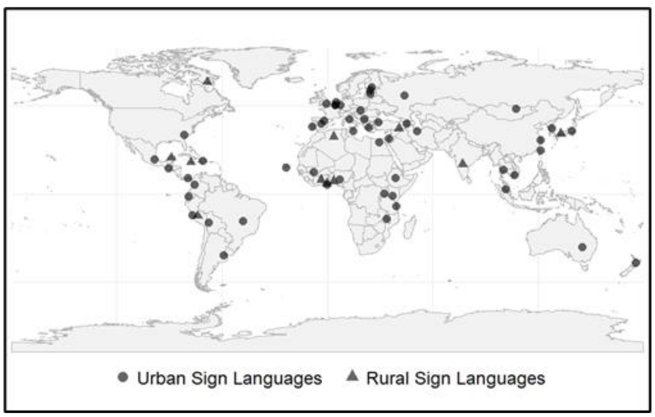

Figure 1: Geographical distribution of the two types of sign languages included in this study.

The resulting dataset consists of the numeration systems of 63 sign languages. Each language was classified as urban or rural based on sociolinguistic criteria reported in the literature, including community size, the presence or absence of formal deaf education, and patterns of language transmission (Zeshan et al., 2013). On this basis, 52 languages (82.5%) were categorized as urban and 11 (17.5%) as rural (see Figure 1). This is an important distinction for our purposes, as these different social ecologies can influence how numeration systems develop and are represented: While urban sign languages typically emerge in large Deaf communities with formal schooling and tend to develop more standardized structures, rural sign languages arise within small communities with a high incidence of deafness, and have been shown to possess typologically unusual features, particularly in the domain of number (De Vos & Pfau, 2015).

For our representational analysis of these systems, we first scrutinized whether they are unstructured or structured around one or more compositional anchors (i.e., numbers to which compositional operations are applied to form the composite numerals in a system). We then identified the main anchor, if present, and assessed whether it also functions as a base (i.e., whether its powers are used to structure the system). For example, 10 is the main compositional anchor in a system if it is the number most frequently used to form composite numerals, but it only qualifies as its base if at least its second power (i.e., 100) is systematically used to structure the system as well. Consequently, if such a system does not extend beyond 99, 10 will be classified as a main compositional anchor but not as a base.

We then focused on how numerical information is represented along the system's dimension(s). On the base dimension, we recorded which numbers are represented in a cumulative and which in a ciphered manner, and whether they are produced using one or two hands. We classified representations as cumulative when the number of extended fingers directly corresponds to the number represented, and as ciphered when conventionalized arbitrary signs are used to represent numbers. On the power dimension, we assessed which representational strategies (integrated, parsed, or positional) are employed at each power. The ways in which these representations are realized in sign languages are discussed in more detail below.

Results

Of the 63 sign languages in our dataset, nearly all (n = 61 [96.8%]) use 10 as their main compositional anchor, and in 58 of these (95.1%), 10 also functions as a base. Only two sign languages (3.2%), both rural, use 20 as their main anchor, and in neither case does 20 qualify as a base. All urban sign languages in our sample use 10 as a base. Conversely, for one third of the rural sign languages that use 10 as their main anchor (3 out of 9), 10 does not qualify as base because the extent of their numeration systems does not reach the next power. Since the great majority of the sign languages surveyed is base-10, we assess the representation of the power dimension for the *tens*, for the *hundreds*, for the *thousands*, and for any *higher powers* as a cluster.

Because our dataset does not contain unstructured numeration systems, we assess the representation of both the base and the power dimension in all systems. A first (somewhat surprising) finding is that the great majority of systems (n = 55 [87.3%]) employs a combination of representational strategies within their numeration systems. Below we present in greater detail how this combination of strategies is distributed in the base and power dimensions.

The Base Dimension

A closer examination of the base dimension shows that cumulative representations are the most common, occurring in 33 of the 63 sign languages surveyed (52.4%). Mixed representational strategies are nearly as prevalent (*n* = 28 [44.4%]). By contrast, purely ciphered representations are extremely rare, found in only two languages (3.2%): Portuguese Sign Language (LGP) and its descendant, Cape Verdian Sign Language. We also examined whether numerals in the base dimension are produced with one or two hands, and this showed that the basic numerals are one-handed in 35 sign languages (55.6%) and two-handed in 28 (44.4%).

As illustrated in Figure 2, most of the sign languages that employ a purely cumulative representation rely on two-handed numeration systems. In these systems, the non-dominant hand is used to represent numbers from 6 to 9 in a transparent manner, hence conveying all the four kinds of numerical information.

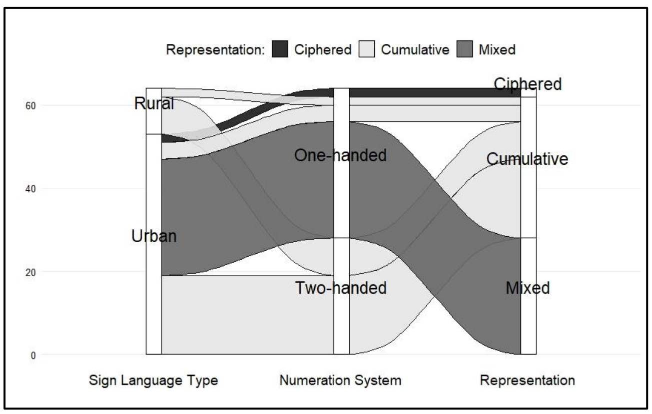

Figure 2: Representation of the base dimension, specified for type of sign language (rural vs. urban) and hands involved in signing basic numbers.

A few exceptions, however, demonstrate that cumulative representation can also be achieved in one-handed systems, namely by employing a secondary anchor. For instance, Korean Sign Language (KSL), Japanese Sign Language (JSL), and Taiwan Sign Language (TSL), all related members of the JSL family, use 5 as a secondary anchor as follows: 1 to 4 are expressed by extending the index through the little finger of the dominant hand. At 5, only the thumb is extended, and numbers 6 to 9 are then represented by raising the index through the little finger again while keeping the thumb extended (Sagara, 2014). In another case, that of Colombian Sign Language (LSC), the representation of the base dimension is kept cumulative on one hand thanks, again, to the use of a secondary anchor of 5. This time, however, the anchor is not represented in an integrated way as in the JSL family, but in a parsed manner: the same fingers extended for 1 to 4 are used for the representation of 6 to 9 but with an added reduplicated flexion of the distal joints (Insor & Instituto Caro y Cuervo, 2006). Finally, two rural sign languages, Miyakubo Sign Language and Mardin Sign Language, adopt yet another set of strategies: In both languages, fingers are extended sequentially to represent numbers 1 to 5 in a one-to-one correspondence. Then, in Miyakubo Sign Language, fingers are placed on the cheek in the same order as in 1 to 4 to produce 6 to 9 (Yano & Matsuoka, 2018), making the representation of the secondary anchor of 5 positional. In Mardin Sign Language, instead, the five extended fingers representing 5 are shown before showing the one, two, or four extended fingers that need to be added to express 6, 7, and 9, respectively[4] (Zeshan et al., 2013).

Interestingly, all the sign languages that represent numbers in the base dimension through a combination of cumulative and ciphered strategies (labelled "mixed") are urban sign languages and have one-handed systems (Figure 2). All, except for Brazilian Sign Language (Libras), in which 5 is ciphered too, make use of the five fingers of the dominant hand in one-to-one correspondence to represent numbers 1 to 5 and then switch to a ciphered representation of the numbers 6 to 9. It is in this latter range where the highest degree of cross-linguistic variation emerges: Some sign languages use handshapes inspired by numerical notations (e.g., Western numerals in Ugandan Sign Language and Libras, and Eastern Arabic numerals in Turkish Sign Language), others adopt the conventionalized counting gestures of the respective hearing cultures (e.g., Chinese Sign Language). In still other cases, the symbolic representation of the numbers 6 to 9 results from a new rule, such as touching the thumb to the tip of each finger in succession, beginning with the little finger (as in ASL and several related languages) or changing the order in which fingers are raised (as in Dutch Sign Language).

The Power Dimension

The analysis of the power dimension reveals that most of the sign languages in our dataset (*n* = 56 [88.9%]) combine differing types of representational strategies across powers, and sometimes even within the same power. Of the seven sign languages that stick to one representational strategy in the power dimension, six are rural (four employing only integrated and two only positional representations) and just one is urban, namely DGS, which employs only parsed representations.

The most common type of representations in the tens is integrated (*n* = 51), followed by parsed (*n* = 38) and positional (*n* = 35). The hundreds are mostly represented in a parsed manner (*n* = 44), followed by positional (*n* = 16) and only in a few cases integrated (*n* = 8). Parsed representation is also the one most common in the thousands (*n* = 54), while integrated (*n* = 4) and positional (*n* = 3) rarely occur. Beyond the thousands too, the representation is mostly parsed (*n* =

[4] In Mardin Sign Language, 8 is represented by the four extended fingers used for the representation of 4 with an added downward movement, which makes 8 a composite numeral, too, but one not relying on an anchor of 5.

41), with a few cases of integrated representation (n = 4) and none of positional (Figure 3).

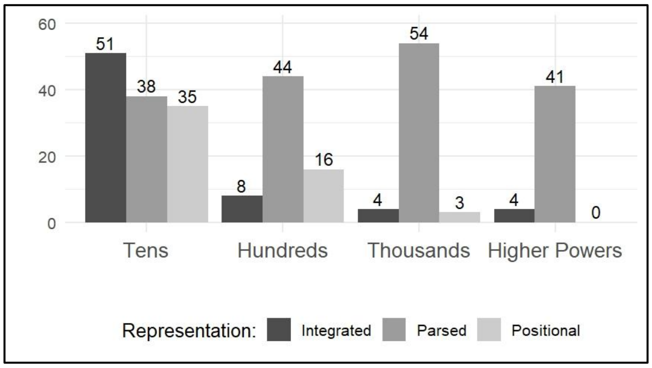

Figure 3: Frequency of integrated, parsed, and positional representations at each power (tens, hundreds, thousands, and any higher powers as a cluster) in the power dimension.

To better understand the possible reasons for their distribution across powers, we will now explain how each representational strategy is achieved in sign languages.

Integrated representation Integrated representation is achieved by introducing a new representational token that represents both the base raised to a given power and its multiplier. This requires either using a new sign for each combination of base and multiplier, greatly expanding the set size, or repeating the original sign multiple times, resulting in long expressions that quickly exceed the subitizing range, and thus become difficult to track. It is therefore unsurprising that the only four cases in which integrated representations are employed as the sole strategy are rural sign languages. Indeed, only the low extent of their numeration systems, often not reaching the next power, makes it possible to repeat the same sign multiple times without losing track of the count.

Although the urban sign languages in our sample never employ integrated representation as the sole representational strategy, integrated representations are sometimes used when 1 is the multiplier and abandoned in favor of other representational strategies for the subsequent multipliers.

Positional representation Positional representation is achieved almost exclusively through what is known as "digital strategy" (Zeshan et al., 2013). This involves sequentially signing numerals one after the other, typically with a movement from left to right. For instance, the number 23 could be expressed by producing TWO followed by THREE. Importantly, while this order corresponds to the visual layout of written Western numerals for the signer, it is perceived in reverse by the recipient, who sees TWO on the right and THREE on the left. Thus, what determines the positional value is not the spatial position per se, but rather the temporal sequence in which the signs are presented.

An exception to the predominant use of the digital strategy occurs in Maltese Sign Language (LSM). In LSM, the signs TEN and ELEVEN are produced with the left hand signing ONE and the right hand simultaneously signing ZERO or ONE, respectively (Azzopardi-Alexander & Azzopardi, 2003). This construction introduces a different kind of positional representation, also attested in body-based numeration systems (e.g., Skribnik, 1996), in which it is the position on the body, and not the temporal sequence, that encodes numerical value; in this case the left hand stands for the tens and the right for the units. However, unlike in body-based numeration systems, this strategy is used only for specific numerals, not across the entire system, and it clearly reflects how these numbers are written in the Western numerals.

Parsed representation One strategy to achieve parsed representation in sign languages is to introduce a new sign to represent the base raised to a specific power, while reusing an existing sign to indicate the multiplier. This strategy is particularly common beyond the hundreds, where the newly introduced signs are often initialized forms based on the written words for thousand, million, and billion. Such is the case, for example, of MILLION and BILLION in Australian Sign Language (Auslan) (Johnston & Schembri, 2007). This strategy appears within the hundreds range too, though less frequently.

An equally common strategy, known as "numeral incorporation" (Zeshan et al., 2013), relies on an added movement rather than a distinct sign. However, because movement in sign languages carries semantic weight, it still classifies as a parsed representation. Adding specific movements to existing signs enables altering their numerical meaning without lengthening the overall expression. Although this strategy is particularly effective for linguistic economy, articulatory constraints might limit its applicability. In some cases, for instance, basic numerals already involve movement, making it difficult to layer an additional movement without causing confusion. In others, numerals may be two-handed signs, where adding a movement would be physically cumbersome or perceptually unclear. As a result, some sign languages employ this strategy only for the numerals that allow it, while relying on parsed representations with new signs for those that do not.

Finally, though rarely, parsed representation may also be conveyed through a non-manual modification of an existing sign. In Sivia Sign Language, for example, 20 to 100 are produced by signing TWO to TEN accompanied by an open mouth (INTENSE morpheme) or a wrinkled nose and grimace (Clark, 2017).

Discussion

The analysis of how sign languages represent numbers across the base and power dimensions has revealed the combination of representational strategies at a degree seldom attested in notational or verbal numeration systems. In the following, we discuss the cognitive implications of these patterns, focusing first on the base dimension and then on the factors driving the distribution of strategies in the power dimension.

Cognitive implications of cumulative vs. mixed representations

How a system represents numerical information on the base dimension strongly influences the cognitive load incurred when using the system. Fully cumulative representation makes all numerical information explicit while ciphered do not. When mixed systems shift to ciphered forms, normally beyond 5, they do so to keep the representation one-handed. Importantly, these ciphered representations are often not as cognitively costly as one might think, because they draw on already familiar symbols (e.g., conventionalized counting gestures or shapes resembling notations) or follow a single productive rule. This familiarity or rule-based regularity helps offset the loss of explicit ordinal, interval, and ratio information, making ciphered representations easier to learn and process than their abstractness would suggest. The fact that all mixed systems in our dataset are urban and one-handed further indicates that pressures for articulatory economy outweigh the cognitive benefits of fully cumulative representation.

Variation in the power dimension

The power dimension shows substantial mixing of representations because each of them comes with different advantages and constraints in the visual-manual modality. Variation is greatest for the representation of the tens, likely because many sign languages express 10 in an integrated way and then shift to other strategies for the following multipliers. A more targeted analysis of the tens, controlling for the representation of 10 and possibly of the teens, is needed to clarify how representational strategies are employed at this power (Anceschi et al., subm.).

As mentioned, integrated representation is poorly suited for expressing higher numbers in the visual-manual modality, which explains why their frequency drops sharply beyond the tens. Positional representation exhibits a similar decline: Although the digital strategy in principle is highly efficient in expressing large numbers without need to introduce new signs or rules, it is constrained in this format by working-memory limitations. Tracking long sequences of numerals becomes increasingly difficult, especially because the place value of each sign cannot be determined until the full sequence is complete. For this reason, the digital strategy rarely appears beyond the hundreds, and when it is used at higher powers, it typically occurs in predictable contexts such as expressing years in dates, where contextual knowledge enables the recipient to anticipate the place value of each numeral as it is produced.

Parsed representation, by contrast, becomes increasingly common as powers rise, and dominate by far in the hundreds, thousands, and higher powers. Interestingly, parsed representation is also the one most used in spoken languages (Bender & Beller, 2015). Their prevalence likely reflects the fact that in parsed representation the powers and the multipliers are externally separable and thus require less cognitive effort. The choice of which strategy to use – whether introducing a new sign or using numeral incorporation – seems to largely depend on phonological and articulatory constraints, but in future work, we aim to examine more systematically how these two parsed strategies are distributed across powers.

Limitations and open questions

The main limitation of this study concerns the availability and quality of data. Documentation of numeration systems varies widely across sign languages, and in some cases our analysis relied on dictionaries or teaching materials rather than detailed linguistic descriptions, which may omit important information. A further issue is the coexistence of multiple numeral variants within some languages, some of which also employ different representational strategies. Although such variation can provide valuable insights into system development, it typically requires rich contextual information for disambiguation that was not available in most sources. We therefore selected the variant reported as most common, acknowledging that this may have oversimplified the systems.

Beyond these limitations, the patterns uncovered in this study leave some questions open. The first relates to the cognitive implications of different representational strategies, which remain largely theoretical in the absence of direct experimental evidence assessing their associated cognitive demands in sign language numeration systems. The second relates to the evolutionary implications of our findings. Because our analysis does not account for language family, it is difficult to determine whether similarities across systems reflect independent developments or are due to shared history or contact between languages. Some individual cases suggest possible shifts in representational strategies, for instance, from purely cumulative to mixed representations, which may point to pressures for articulatory economy in the evolution of systems. However, the available evidence does not support a unidirectional trajectory, and previous work has shown that system type (one- or two-handed) is not predicted by language age (Semushina, 2021). More generally, there is currently insufficient evidence to identify clear evolutionary paths across systems, and addressing these questions will require richer diachronic data as well as integrated typological and experimental approaches.

Conclusion

This study presents the first systematic representational analysis of numeration systems in sign languages, focusing on the representation of numerical information across the base and power dimensions. Our findings show that sign languages combine representational strategies in ways that differ from numerical notations and verbal systems, reflecting the unique affordances and constraints of the visual-manual modality and highlighting the importance of including them in the comparative study of numeration systems.

Acknowledgments

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme for the project *Evolution of Cognitive Tools for Quantification* (QUANTA), grant agreement no. 951388, and from the Research Council of Norway through its Centres of Excellence funding scheme for SFF *Centre for Early Sapiens Behaviour* (SapienCE), project number 262618.

AI-assisted technologies were used as an aid in writing the R code for data visualization.

References

Anceschi, C., Dudojć, O., & Bender, A. (submitted). The strange behavior of numbers in their teens: A comparative analysis of numerals 11 to 19 in sign languages. Manuscript submitted for publication.

Azzopardi-Alexander, M., & Azzopardi, M. (2003). *Dizzjunarju: Il-lingwa tas-sinjali Maltija = Maltese sign language dictionary* (R. Zammit, Ill.). Fondazzjoni Żvilupp Lingwa tas-Sinjali Maltija.

Bender, A., & Beller, S. (2012). Nature and culture of finger counting: Diversity and representational effects of an embodied cognitive tool. *Cognition*, *124*(2), 156-182.

Bender, A., & Beller, S. (2018). Numeration systems as cultural tools for numerical cognition. In D.B. Berch, D.C. Geary, & K. Mann Koepke (Eds.), *Language and culture in mathematical cognition* (pp. 297-320). Academic Press.

Bender, A., Schlimm, D., & Beller, S. (2015). The cognitive advantages of counting specifically: A representational analysis of verbal numeration systems in Oceanic languages. *Topics in Cognitive Science, 7,* 552-569.

Chrisomalis, S. (2004). A cognitive typology for numerical notation. *Cambridge Archaeological Journal*, *14*(1), 37–52.

Chrisomalis, S. (2010). *Numerical notation: A comparative history*. Cambridge University Press.

Chrisomalis, S. (2020). *Reckonings: Numerals, cognition, and history*. MIT Press.

Chrisomalis, S. (2025). Base structures across lexical and notational numeral modalities. *Philosophical Transactions B*, *380*(1937), 20240217.

Clark, B. R. (2017). *A grammatical sketch of Sivia Sign Language* [Doctoral dissertation, University of Hawai'i at Mānoa].

De Vos, C., & Pfau, R. (2015). Sign language typology: The contribution of rural sign languages. *Annu. Rev. Linguist.*, *1*(1), 265-288.

Dudojć, O., Bender, A., & Anceschi, C. (2025). Handy numerals: Compositional elements in body-based numeration systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *380*(1937).

Insor (Instituto Nacional para Sordos), & Instituto Caro y Cuervo. (2006). *Diccionario básico de la lengua de señas colombiana*. Insor (Instituto Nacional para Sordos).

Johnston, T., & Schembri, A. (2007). *Australian Sign Language (Auslan): An introduction to sign language linguistics*. Cambridge University Press.

Pelland, J.-C. (2025). A glossary for the cross-disciplinary study of numerals. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *380*(1937).

Sagara, K. (2014). *The numeral system of Japanese Sign Language from a cross-linguistic perspective* [Doctoral dissertation, University of Central Lancashire].

Semushina, N. (2021). *The linguistic representation of number: cross-linguistic and cross-modal perspectives*. University of California, San Diego.

Skribnik, E. K. (1996). Finger-counting with Buryats and Evenkis in Siberia: Buryat finger-counting. In S. A. Wurm, P. Mühlhäusler, & D. T. Tryon (Eds.), *Atlas of languages of intercultural communication in the Pacific, Asia, and the Americas* (pp. 1037–1038). De Gruyter Mouton.

Widom, T. R., & Schlimm, D. (2012). Methodological reflections on typologies for numerical notations. *Science in Context*, *25*(2), 155–195.

Yano, U., & Matsuoka, K. (2018). Numerals and timelines of a shared sign language in Japan: Miyakubo Sign Language on Ehime-Oshima Island. *Sign Language Studies*, *18*(4), 640-665.

Zeshan, U., Escobedo Delgado, C. E., Dikyuva, H., Panda, S., & De Vos, C. (2013). Cardinal numerals in rural sign languages: Approaching cross-modal typology. *Linguistic Typology*, *17*(3), 357-396.

Zhang, J., & Norman, D. A. (1995). A representational analysis of numeration systems. *Cognition*, *57*(3), 271-295.

Zhang, J., & Wang, H. (2005). The effect of external representations on numeric tasks. *The Quarterly Journal of Experimental Psychology Section A*, *58*(5), 817-838.