The deaf way of interpreting mathematical concepts

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ABSTRACT

In this article, we focus on mathematical problem-solving articulated by native signers in Finnish Sign Language (FinSL) and discuss how to render this kind of linguistic behaviour understandably in its completeness. The phenomenon – calculating aloud in a visual manner – is still very commonplace in the Finnish deaf culture. The linguistic process itself is intelligible for native signers monitoring the calculation, but to our experience, these mathematical narratives have mostly passed unobserved and remain a mystery to outsiders. One of the reasons may lie in the fact that a mathematical discourse conducted by a deaf person can be misconstrued as "counting with fingers".

Numerous studies have shown that deaf children and adults lag behind hearing individuals in terms of arithmetical and mathematical performance. Deaf students' performance remains constantly "below basic level". Deaf students' learning difficulties in mathematics are seen as being related to linguistic problems but this bias should be revisited. It is possible that deaf peoples' way of counting has not been correctly understood and interpreted into spoken language to the researchers. In few research articles have been postulated the possibility that deaf people should be allowed to also use visual linguistic strategies when testing their abilities in mathematics.

Besides short descriptive articles, mathematical narratives in sign language have not been an object of interest in handbooks of FinSL or for other sign languages of which we are aware. This is why this linguistic genre may remain opaque for hearing non-native sign language interpreters, too. Mathematics is one of those specialties where, not only native users of sign language, but especially people raised in the deaf community would be needed as intermediaries explaining the conceptual differences between the two operational cultures – deaf and hearing – interpreting the phenomena of the mathematical universe.

Keywords: calculations, deaf mathematics, FinSL

1 INTRODUCTION

When deaf adults calculate mentally, they often use their hands to perform extremely minimal but highly visible movements (see tinyurl.com/maths-FinSL). Similar mathematical behaviour can still be found among modern merchants e.g. in Africa and Oseania; this phenomenon was not foreign to people of ancient times either (Ifrah, 1994). Despite the fact that the phenomenon of using hands as a "visual abacus" is a very commonplace linguistic activity in the Finnish deaf community and in our everyday language use, it has remained unnoticed in sign language teaching for interpreters, not to mention the fact that it was never, to our knowledge, used in teaching mathematics in sign language medium schools for the deaf.

Apart from being misconstrued as calculation with fingers, another possible explanation why this calculation method cultivated within the deaf community has been overlooked may lie in the fact that the processes are complicated to transliterate or translate comprehensibly into spoken languages (Rainò et al., 2014). Remaining as an unknown practice[1] for the non-native interpreters the "deaf way of calculation" may be misleadingly interpreted. Huovila (2013, p.18) reports encountering hearing sign language interpreters (SLIs) who erroneously translated deaf pupils' reasoning during her mathematics courses as they were not aware the process of addition and subtraction starts from "the right to left", i.e. from bigger to smaller units (see figure 2).

We have utilized this Erasmus+ project to create a collection of educational material for the use of both deaf and hearing sign language interpreter (SLI) students attending our training programme at the Humak University of Applied Sciences (Humak UAS). With various textual examples containing monologues and dialogues on mathematical problem solving, modelling the conceptualization of mathematical entities in FinSL, we seek to offer not only diverse ways of approaching and problematizing mathematics tasks but also examples for their multimodal interpretation and translation.

In this paper, we present some examples of signed mathematical monologues conducted by deaf people using Finnish Sign Language (FinSL). It has to be noted, though, that in our efforts to keep the metatext simple when interpreting the performance in written language, we were required to describe simple mathematical tasks. This spatially and visually complex phenomena would, in fact, require another mode of publication than the printed word, e.g. a multimedia format possibly exploiting the affordances offered by the augmented reality.

2 THEORY

In numerous studies from this and last century researchers have repeatedly shown that deaf people lag behind hearing individuals in arithmetical and mathematical performance (e.g. Frostad, 1999; Nunes and Moreno, 1998; Kelly et al., 2002; Foisack, 2003; Hyde et al., 2003; Kelly et al., 2003; Lang and Pagliaro, 2007; Bull, 2008; Kritzer, 2009; Foisack et al., 2013; Pagliaro and Kritzer, 2013). This result should, however, be questioned since the studies (except those of Foisack, 2003, Pagliaro and Ansell, 2012, and Lindahl, 2015 regarding natural sciences) do not show evidence that the deaf subjects have had the opportunity to apply calculation strategies cultivated in sign language when participating in (written) assessments. Another regrettable fallacy is that deaf students' learning difficulties in mathematics are related to their linguistic problems connected to the written language.

This article is based on the observations by Huovila, Rainò and Seilola (e.g. Seilola and Rainò, 2008; Huovila et al., 2010; Rainò et al., 2010, 2013, 2014) and analyses of their data of a corpus of monologues and dialogues in FinSL where deaf adults present and discuss arithmetic calculations. Besides these articles there are, to our knowledge, no other linguistic analyses conducted in Finland. Elsewhere we find random observations made by Foisack (2003, Section 6.2) for children using Swedish Sign Language (SSL) and Pagliaro and Ansell (2012) for children using American Sign Language that have studied in depth deaf peoples' linguistic behaviour when solving mathematical problems. And in her dissertation Lindahl (2015) analysed discourses conducted in SSL concerning concepts and phenomena in physics and organic chemistry. Lindahl (2015) has also conducted research on collective meaning creation processes between mathematics teachers, science teachers and deaf bilingual pupils in a multimodal context, exploiting the framework of translanguaging (see for example García 2009, García and Sylvan, 2011).

In their "mathematical thinking-aloud" Finnish deaf people use fingers, both hands and three-dimensional neutral space in front of the signer extremely systematically (see Rainò and Seilola, 2008 for a discussion of addition, subtraction, division and multiplication). Fingers and hands with their movements in space have special roles where all of these elements are used as buoys (Liddell, 2003) when calculating and anchoring, for example, totals and subtotals in "a visual abacus".

1. One of the factors that has kept "the deaf way of calculating" under cover may be the commonplace thinking that "calculating with fingers" is considered a sign of immature mathematical abilities. Recent neurological findings, however, show the opposite, Berteletti and Booth (2015) maintain that educational practices should encourage the use of fingers as a functional link between numerical quantities and their symbolic representation as well as an external support for learning arithmetic problems.

This shows the relationships between the numbers and results of calculations, while the actual calculations are performed mentally (Seilola and Rainò, 2008; Rainò et al., 2013, 2014.)

The processes described above differ completely from number representations in sign language (studied in adult deaf signers by Korvorst et al., 2007). In FinSL, for instance, cardinal and other sequential numbers are one-hand signs produced with the dominant hand. When signing, for instance, the first nine cardinal numbers (1–9), the palm orientation is towards the signer with fingers pointing straight up (cf. ‘1’ in Figure 1a). 'Tens' are signed with a slight movement downwards (as in Figure 2a), whereas ‘hundreds’ contain a horizontal movement to the side with fingertips pointing towards the centre line (Figure 1b). Corresponding ordinal numbers, taking only one domain of the many semantic domains of morphemes for numeral, are produced by varying the palm and finger orientation and the position of the hand in the space. (Suvi, 2018, *Numeraalit* [Numerals].)

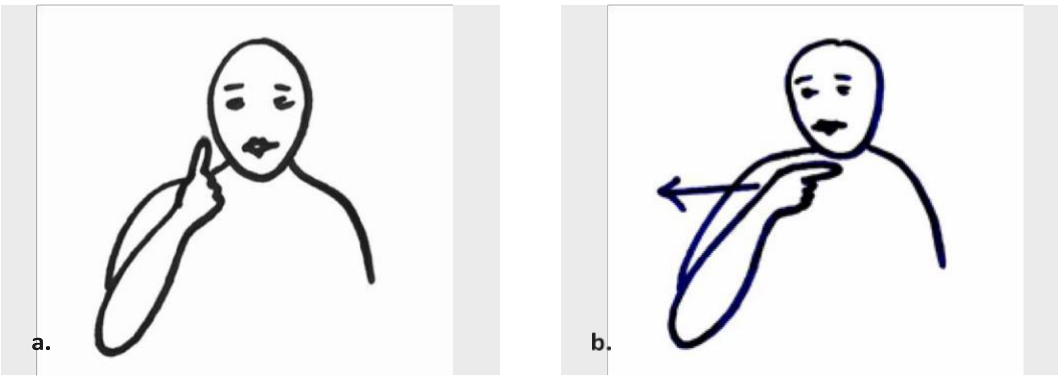

Figure 1. Cardinal numbers 1 (a) and 100 (b) in FinSL.

When signing calculation the orientation of palm and fingers roughly follows that of cardinal numbers but the hands are kept lower in the signing space and tilted slightly away from the signer (as in figures 2 and 3). When a signer performs or illustrates a calculation, they may watch their fingers, which is never the case in normal discourse (unless the signer is recalling something and repeating his or her words sign by sign). The calculation process is illustrated below with two simple examples (figures 2 and 3; cf. Rainò et al. 2013). In a task of addition (23 + 23) the signer

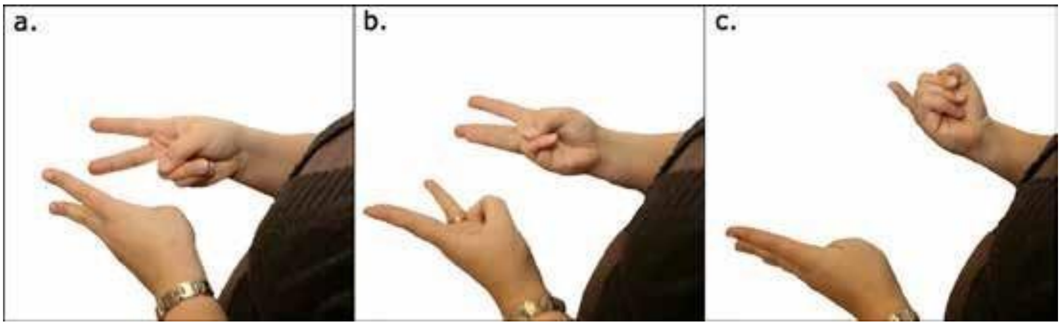

Figure 2. Counting aloud 23 + 23 in FinSL (Rainò et al., 2013).

would first place tens in both hands (Figure 2a) then move the sum (40) to “the intermediate memory” on the non-dominant hand (Figure 2b), after which ones (3+3) would be added to the fingers of the dominant hand producing the sum 6 (Figure 2b–c).

Figure 3 illustrates the special use of visual abacus in multiplication. During the calculation process of 3 x 8 the signer first splits the task into sub-calculations (2 x 8 + 8) anchoring eights one by one with the dominant hand (representing the cardinal number 8) by touching the index and middle fingers of the non-dominant hand “with the 8” (Figure 3a). Then the two values (8 + 8) are fixed into a group of two entities on the non-dominant hand (Figure 3b), while the intermediary

Figure 3. Calculating 3 x 8 in FinSL (Rainò et al., 2013).

sum (16) is temporarily visualized on the dominant hand (Figures 3b-c) which could be considered as a list buoy (Liddell, 2003). Subsequently, the signer transfers the sum 16 to ’the intermediate memory’ with a small inward movement to herself. Then the third value (8) is added to the group of two 8s, waiting in the non- dominant hand. Eventually, the final sum (24) is produced and signed with the dominant hand.

As these manual calculations are performed in fragments of seconds, with both hands active individually and simultaneously, the multidimensionality creates problems not only for traditional coding and notation systems used in sign language research but also for interpreting into a spoken or written language (e.g. in Finnish or English). If we consider the coding of multiplications and fractions to glosses, using traditional terms from a spoken/written language is challenging since the objects in the calculation task, e.g. *multiplicand and multiplier or numerator* and *denominator* are found and manipulated simultaneously in both the dominant and non-dominant hands. Besides, a consecutively progressing (spoken or written) language is not able to give justice to the calculation speed in sign language and neglects how the different locations in space are occupied by the “unseen” numeric values in the ongoing discourse.

When interpreting instances of anchoring numeric values, the target text could be more accurate if the conceptualization used for synesthetic descriptions were applied. Even a multimodal representation of the visual experience could provide a solution, as shown in the experiment by Rainò et al. (2014; see figures 4 and 5). They produced a surtitled videotape (tinyurl.com/ maths-FinSL) attempting to visualise the speed and flow of the mental calculation processes.[2] In this videoclip the conceptualization of the “empty” spaces occupied with numeric values are shown. They are being marked and memorized, not only by the deaf informants themselves but also by other native users of FinSL monitoring the process. This demonstrates that there is a collective understanding behind the mathematical reasoning among the sign language users.

2. We thank Mr. Mikko Palo from the Mediapalo enterprise for his valuable contribution for the numeric animation of the videoclip.

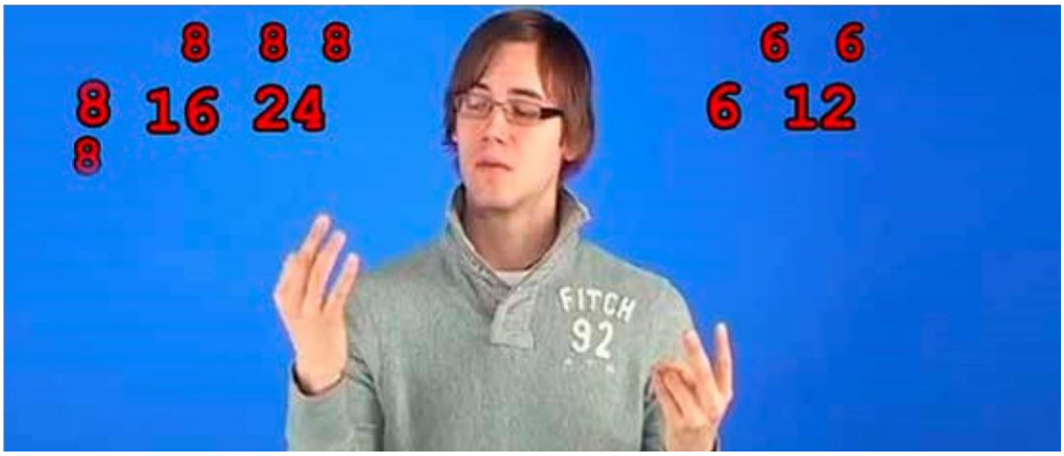

Figure 4. The process of calculating (8+8+8) + (6+6) as visualised in a surtitled videoclip. (Rainò, Huovila and Seilola 2014; tinyurl.com/maths-FinSL)

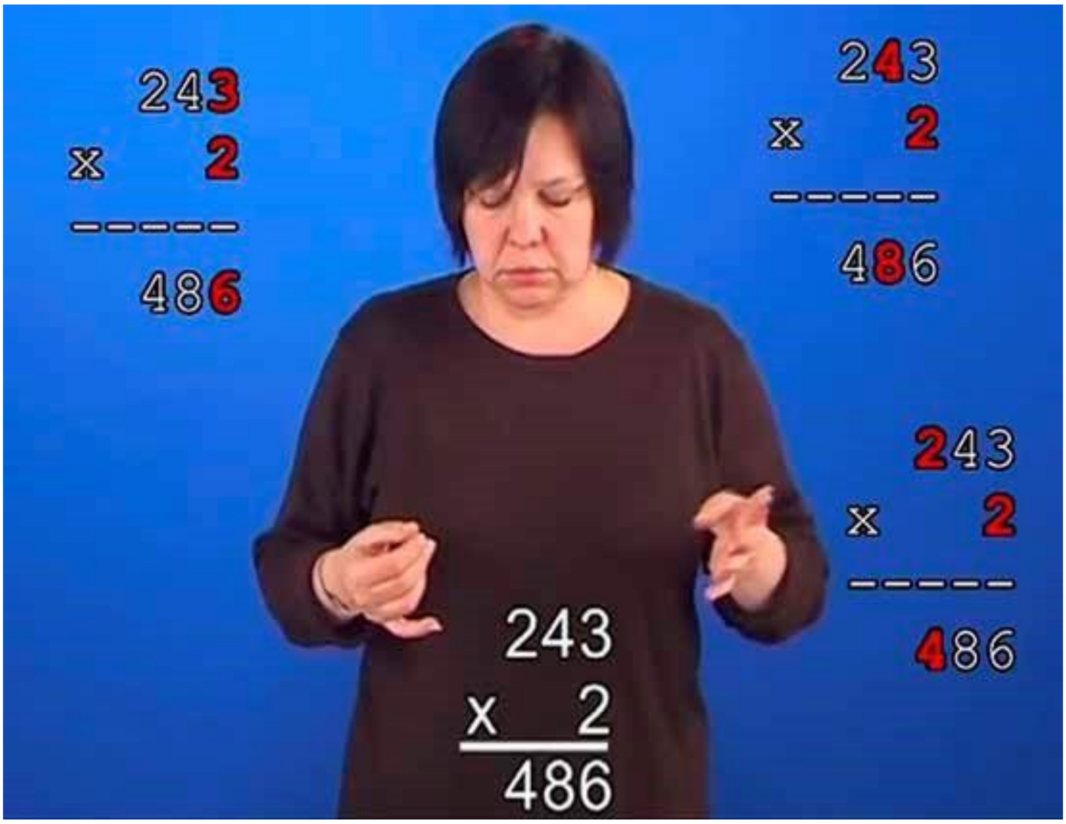

Figure 5. Intermediary phases of the task 2 x 243 as visualised in a surtitled videoclip. (Rainò, Huovila and Seilola, 2014; tinyurl.com/maths-FinSL)

Even though it may be beyond the scope of this paper, we feel obliged to mention that in a similar manner fingers, hands and the body have been used as an abacus in former times, e.g. in Egypt, Persia, Romans and in Europe in the Middle Ages. See an example by Pacioli in Figure 6 reported in Ifrah (1994). Ifrah mentions the Venerable Bede's (ca. 672–735) publication [Tractatus de computo, vel loquela per gestum digitorum] and "the language of numbers" or finger reckoning (Ifrah 1994; cf. Beda Venerabilis [725, 1525]1843).

Figure 6. In his Summa de arithmetica Luca Pacioli ([1494] 1523: 36) illustrated how units, tens, hundreds and thousands could be calculated and memorised by using different constellations of fingers in the left and right hand.

3 MOTIVATION OF THE STUDY AND ITS OBJECTIVES

Rainò (2010) and Raino et al. (2013) noticed that hearing teachers (non-native in sign language) teaching mathematical-linguistic operations may have different cognitive premises from those of their deaf students. As mentioned earlier, these differences in mathematical conceptualizations challenge even non-native sign language interpreters (Huovila, 2013). When teachers talk about mathematical operations such as fractions in spoken Finnish and it is consequently interpreted into FinSL, the epistemic knowledge of the concepts 'denominator', 'numerator' and 'fraction' is constantly discussed. This presupposition of the importance of the "ubiquitous terminology" and universal conceptualisations of mathematical entities surfaces clearly in the glossary of mathematics terms published for the use of deaf schools (Rainò, 2010, cf. Figure 7 and 8).

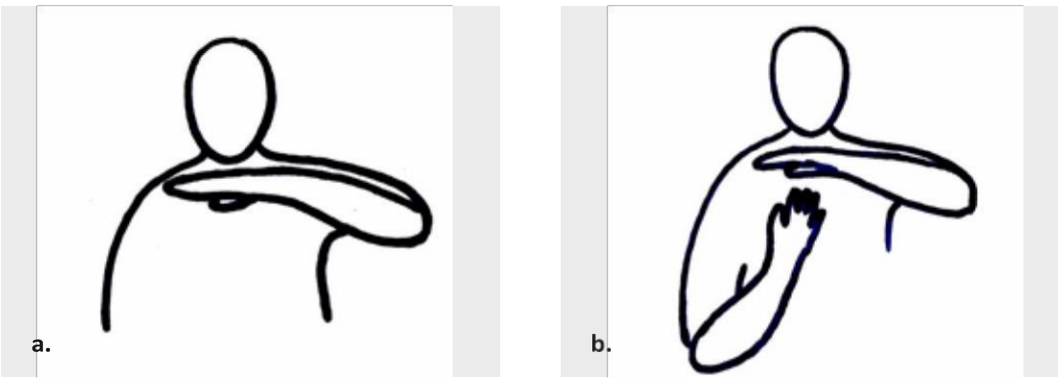

Figure 7. A sign representing 'denominator'. Reproduction of the lexeme is based on the vocabulary for mathematical signs for deaf schools (Varonen, Laaksonen and Hyyppä, 1999).

Deaf people, however, do not use the borrowed conceptualizations and terms when problematizing and tutoring each other in mathematics. Sentences translated from Finnish mathematical discourse such as "What is a nominator?" or "Where is the denominator?" are void of meaning in idiomatic FinSL because the concepts with all their semantic elements are present in one holistic but complex sign. Consequently, if a teacher asks "What is the value of the denominator… if

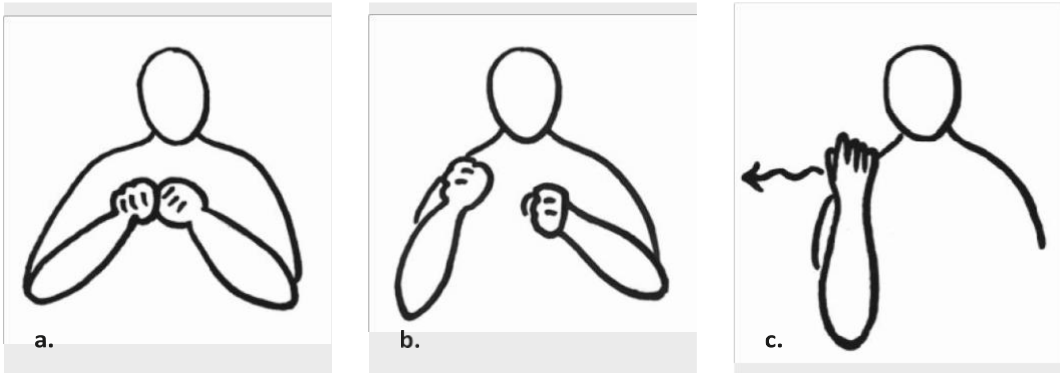

Figure 8. A sign representing 'fraction'. Reproduction of the lexeme is based on the vocabulary for mathematical signs for deaf schools (Varonen, Laaksonen and Hyyppä, 1999). The sign is a direct loan from Finnish, following the original term's semantic and syntactic structure: murto/luku (< 'fract, break' + 'number').

you should cancel the fraction 8/4?" interpreted into FinSL the task would be incomprehensible and absurd, since the answer (as well as the concepts for "nominator", "denominator" along with the "fraction" and the values 8 and 4) are all present in the signed question – unless the discussion would be conducted using meta-language about written Finnish in a mathematical discourse (see figure 9) (Rainò, 2010; Rainò et al., 2013).

Figure 9. Dialogue in FinSL on cancelling the fraction 8/4 (Rainò et al. 2013).

4 RESULTS

In this project our intention was to gather further examples of mathematical texts for the use in SLI training that would provide challenges when transliterating and translating and in modalities other than written and spoken Finnish. During a session organised with Viparo enterprise (an employer of deaf translators and interpreters) a collection of mathematical tasks used in adult vocational education were translated into FinSL. Some of the calculations were also spontaneously solved by "signing them aloud" (see tinyurl.com/maths-FinSL-2 for a representation of some of the calculation tasks with English surtitles). Due to the limited space at our disposal, we present here one of the samples where the signer (and author of this article) proceeds towards a solution of the task, calculating the percentage share of four compared to twenty.

Figure 10 presents the series of images edited from the video with a translation into English. However, the linear translation does not succeed in accurately reproducing the spatial relationship between the entities 4 and 20 in the numeric universe in front of the signer. The still images also flatten the spatial depth so that the differences of "the spatial values" anchored in front of the signer are not readily observable.

So how many percent of four is twenty? [In order to approach 20] you need to take a 4 and add another 4, arriving to 8 …

… Then you add another 4, you get twelve, another, it's sixteen, and then twenty. So five…

… times you need to approach [the entity of 20] with the 4 and then you get 20. If 4 is 100…

… percent, then five times – right, twenty must be five hundred percent!

Figure 10. Mathematical problem solving in FinSL: thinking aloud "how many percent of four is twenty?" (tinyurl.com/maths-FinSL-2)

In our opinion the clue to the solution (500 %) as seen in Figure 10 and therefore "the deaf way of reasoning" can be found when we look beyond the words and signs and focus on the rhythmically diminishing space "measured by fours" between the initial values of 20 and 4. Without animation and other imagery techniques at our disposal these suprasegmental visual clues in the signed discourse remain, difficult to teach non-native sign language users. And it is precisely on this epistemic grounds where deaf native sign language users; deaf translators and interpreters are needed to shed light on the sophisticated prosodic elements in the flow of information. They are able to pass these unique approaches in solving mathematical (amongst others) to non-native signers so that they can be transferred in their fullness in language in a different modality.

5 DISCUSSION

In collecting multiple instances of mathematical discourse in Finnish Sign Language (FinSL) we aimed to bring the mathematical reasoning conducted by deaf people into the spotlight. This kind of linguistic and intellectual behaviour has to date been ignored by both researchers of sign languages and those evaluating the mathematical skills of deaf people. Although outside the scope of this paper, we assume that the reasons behind the poor performance of deaf examinees in mathematics is the linguistic (and a cultural) glass ceiling created, at least partly, by the lack of knowledge of deaf peoples' mathematical actions and the challenges it poses for translation and interpretation.

As noted above only a few studies can be found where deaf students' visual problem-solving process and mathematical thinking-aloud discourses in sign language are mentioned (Foisack, 2003 for Swedish deaf pupils; Lindahl, 2015 for natural sciences, including chemistry; Pagliaro and Ansell, 2012 for children using American Sign Language). One possible explanation why the calculation methods developed within the deaf community has been overlooked may lie in the fact that the processes are complex to interpret clearly into spoken languages. As a consequence, it is no wonder that hearing students attending sign language interpreter programmes (at least in Finland) are not familiar with a deaf way of conceptualizing mathematical phenomena but are familiar with the glossaries of mathematics terms translated from Finnish to FinSL. In this paper, we have tried to break this glass wall and also presented examples of possible transliterations for mathematics performances produced in FinSL.

6 CONCLUSION

In their study on recall of mathematics terms by deaf students Lang and Pagliaro (2007) invite researchers to explore the potential of sign language to "enhance the visualisation skills". The true challenge, in our opinion, concerns the gulf between the linguistic expression of mathematical thought between hearing and deaf people. This is also where deaf interpreters are needed as intermediators, to guide non-native signers to understand the "deaf way" of verbalising their abstract thinking and to help outsiders become aware, for instance, of the mathematical universe experienced by deaf people.

One cannot avoid thinking that our western culture with its dominant position has made us blind and even incurious to other ways of counting, cultivated by minorities that exist within our society. For some reason, we expect the same theoretical reasoning from their "collective mind", i.e. that their minds and ways of thinking should always follow that of our own. In 1922 Lévy-Bruhl, a French philosopher, sociologist and ethnologist cited in Ifrah's ([1981] 1994) vast ethnographic collection of different numeric and calculation systems, declared:

> En fait, les numérations comme les langues, don't on ne doit les séparer, sont des phénomènes sociaux, qui dépendent de la mentalité collective. Dans chaque société, cette mentalité est étroitement solidaire du type de cette société et de ses institutions. (Lévy-Bruhl 1922: Section *Les systèmes de numeration*; cf. Ifrah 1994: 116).
>
> In fact, numerals such as languages, which are inseparable, are social phenomena which depend on a collective mind-set. In every society, this mindset is closely linked to the type of society and its institutions (transl. C Stone)

We feel that our scientific obligation is to shed light on the *mentalité collective* of the Finnish deaf people and their collective way of reasoning in mathematical problems. We hope that our article, even in its brievity would also raise interest and curiosity, not only among other sign language researchers but among mathematicians and other scientist to study further the visual counting system of deaf people with different linguistic and educational backgrounds. Augmenting analysis with modern technology with its near to limitless possibilities to display, collect, record, analyse and share signed reasoning would allow us to do this on a global scale.

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