Visualizing the Spatial Working Memory in Mathematical Discourse in Finnish Sign Language

Päivi Rainò*, Marja Huovila[ó], Irja Seilola[†]
*Corpus and SignWiki Project,
Humak University of Applied Sciences & the Finnish Association of the Deaf,
Helsinki, Finland
[ó]Keskuspuisto Vocational College,
Helsinki, Finland
[†]Sign Language Centre, Department of Languages,
University of Jyväskylä, Finland
E-mail: paivi.raino@humak.fi, marja.huovila@keskuspuisto.fi, irja.r.seilola@jyu.fi

Abstract

In this paper, we will present problems that arise when trying to render legible signed texts containing mathematical discourse in Finnish Sign Language.
Calculation processes in sign language are carried out using fingers, both hands and the three-dimensional neutral space in front of the signer. Specific hand movements and especially the space in front of the body function like a working memory where fingers, hands and space are used as buoys in a regular and syntactically well-defined manner when retrieving, for example, subtotals.
As these calculation processes are performed in fragments of seconds with both hands that act individually, simultaniousity and multidimensionality create problems for traditional coding and notation systems used in sign language research. Conversion to glosses or translations to spoken or written text (e.g. in Finnish or English) has proven challenging and what is most important, none of these ways gives justice to this unique concept mapping and mathematical thinking in signed language. Our proposal is an intermediary solution, a simple numeric animation while looking for a more developed, possibly a three-dimensional representation to visualise the calculation processes in signed languages.

Keywords: Finnish Sign Language, mathematical discourse, visual working memory

1. Introduction

Mathematical problem solving discourse in Finnish Sign Language (FinSL) is carried out using fingers, both hands and the three-dimensional, neutral space situated in front of the signer – all of which are used as a kind of visual abacus or a visual working memory during the counting process. The mathematical discourse described here is part of everyday language worth of bringing forward in the corpora and descriptions of signed languages, despite the fact that signed calculations produced by sign language users are still incorrectly interpreted as merely “finger counting”.

This paper deals with the a corpus that consists of seven monologues and six dialogues, in which native users of FinSL solve basic mathematics questions. Excluding literal translations and vocabularies translated from spoken language to sign language, mathematical discourse in idiomatic sign language use has not, to our knowledge, been highlighted in the descriptions of other sign languages than FinSL (e.g. Huovila & Rainò & Seilola, 2010; Rainò & Seilola, 2008).

One of the explanations lies in the fact that the calculation processes are complicated to transliterate (e.g. using glosses) or to translate legibly to spoken languages.[1]

As calculations are performed in sign language, specific handshapes denote numeric entities and moving hand constellations represent constantly varying relationships between those entities. The actual calculations are performed mentally using the visual working memory created in space in front of the signer where fingers, hands and non-manual spatial layers are used as buoys (c.f. Liddell, 2003) with which, for example, subtotals are retrieved in a regular and syntactically well-defined manner.

The use of space in arithmetic (as well as geometric) calculations in FinSL is parallel with the normal use of three-dimensional space in signed discourse where any concrete and abstract entities may be placed in front of the signing person or on her body. After reserving that location, its meaning can be activated by, for example, pointing with an index finger or even a glance until a new referent is introduced. The neutral space in front of the signer is utilized throughout the grammar in all (studied) sign languages, among other things, for pronominalisation, verb agreement and for textual grouping and semantic categorizations where e.g. paratactic items may be grouped horizontally or vertically.

[1] A vast amount of research has been conducted, however, on deaf students’ learning difficulties in mathematics (cf. Bull, 2008; Hyde & Zevenbergen & Des Power, 2003; Kelly et al., 2002; Kelly & Lang & Pagliaro, 2003). Only a few studies mention the fact (for example, Foisack, 2003) that mathematics could be taught in sign language and students’ thinking in sign language and visual problem-solving process could be at least as valid as operating in spoken language and using the terminology of that language.

(On the use of space, see Sandler & Lillo-Martin, 2006; Liddell, 2003; Neidle & al., 2001; Taub, 2001; c.f. FinSL Lukasczyk, 2008; Jantunen, 2003.)

2. Transliteration of signed mathematical discourse

In FinSL, cardinal and other sequential numbers are one-hand signs produced with the dominant hand. When signing the first nine cardinal numbers (1–9), palm orientation is towards the signer with fingers pointing straight up (cf. '1' in Figure 1a). Tens are signed with the palm to the side of the signer and with a slight movement downwards (cf. Figure 2), whereas 'hundreds' contain a straight movement to the side with fingertips pointing towards the centre line (Figure 1b).

Figure 1a: Cardinal numer '1' in FinSL (Suvi, s.v. Numeraalit [Numerals])

Figure 1b: Cardinal numer '100' in FinSL (Suvi, s.v. Numeraalit [Numerals])

Corresponding ordinal numbers – taking only one example of the vast semantic sphere of applicable morphemes for numerals – are produced by varying the palm and finger orientation and the position of the hand in the space. When signing calculations, then, the orientation of palm and fingers follow roughly those of cardinal numbers but hands are kept lower than normally and tilted slightly away from the signer (Figure 2). When a signer performs or illustrates calculations, he/she may watch his/her fingers, which is never the case in normal discourse unless the signer is recalling something and repeating his/her words sign by sign.sign by sign.

Figure 2: Numbers 8 (in the right hand) and 10 (in the left hand) used in calculations

To discuss the denotation of the visual working memory, we present its manifestation in simple tasks like additions and multiplications e.g. 3 x 8. In the example presented here (Figure 3), the calculation is first split into subcalculations: (8 + 8) + 8 where a group of two eights is placed in the index and middle finger of the non-dominant hand. Here, as in normal sign language discourse, hands may represent different entities: e.g. in multiplications the role of multiplicand is represented by the dominant hand and multiplier by the non-dominant hand (Figure 3a-c). In the latter the fingers act as so-called buoys, which represent discourse entities and the spatial relationships between them (cf. Liddell, 2003). In this example, the entity of multiplicand 8 touches the entity of multiplier 3 twice (Fig. 3a), and the intermediary sum 16 is produced with the right hand (Fig. 3b-c). Subsequently, the signer transfers the number 16 to memory in the intermediate space with a small inward movement until a third 8 is added producing the final sum, 24.

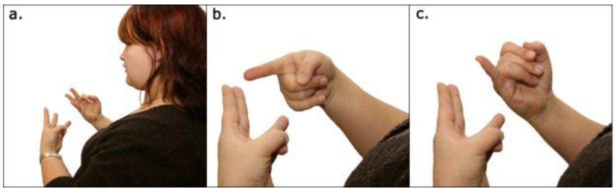

Figure 3: The process of calculating *3 x 8* in FinSL: 'The entity of *multiplicand 8* touches the entity of *multiplier 3* => 8 + 8 = 16 [+ 8 = 24]

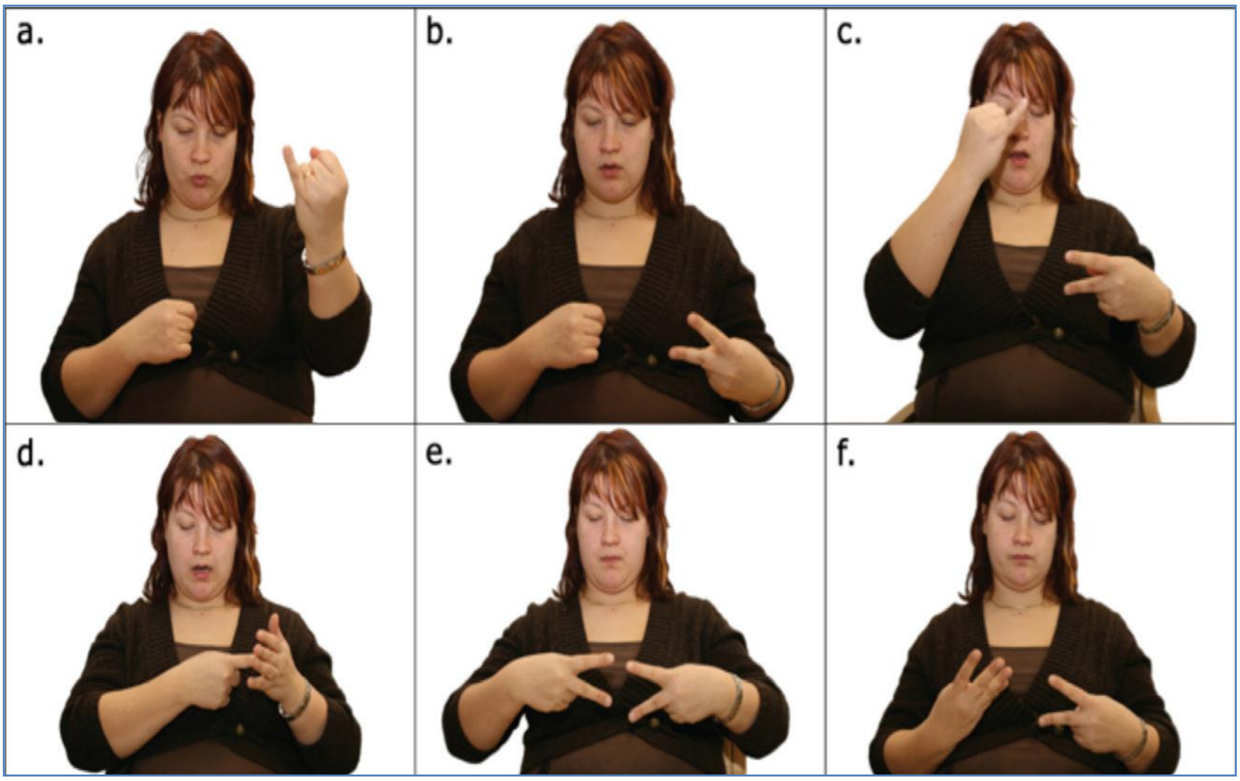

Figure 4: Calculating (3 + 3) x 2 + (3 + 9).

Besides transferring the intermediate sums with a slight movement inwards towards the signer, they can be kept in mind holding the sum in the non-active hand or positioning the sums higher in space as it were a scratch pad as can be seen in Figure 4: The first sum (3 + 3 = 6) is placed up on the left-hand side (Fig. 4a). The sum of the second calculation in brackets (3 + 9 => 12 is being signed (Fig. 4b) and kept in the intermediate memory in the signer's left hand while the 6 in memory is multiplied by 2 (Fig. 4c-d). Then the first sum (12) is taken in the right hand visualised next to the buoy '12' in the left hand (Fig. 4e). Finally, the (two) tens are moved into the non-dominant left hand and the ones into the dominant right hand (Fig. 4f). – The final sum (24), is signed using the normal orientation for cardinal numbersand using the dominant hand.

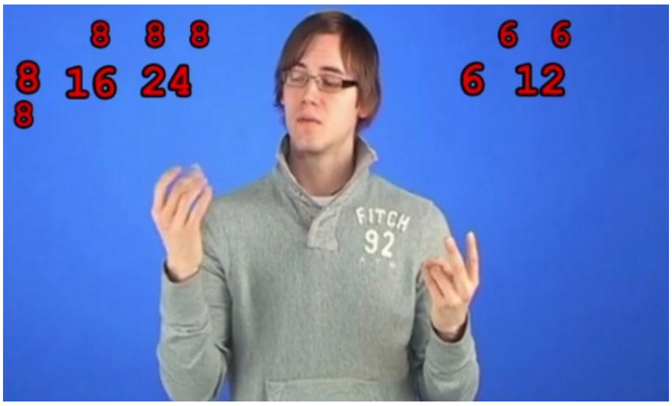

Figure 5: Visualising the process of calculating (8+8+8) + (6+6). (Animation by Mikko Palo)

3. Conclusion

When mathematical reasoning in sign is rendered in a textual representation of a spoken language (compare to the captioning of Figure 4 above), it transforms the calculation

process and the function of the hands and spatial layers in the mental scratch pad unintelligibile for the reader (or listener of the interpretation).

This is why we propose an intermediary solution – a simple numeric animation added as a layer on the video – while looking for a more developed, possibly a three-dimensional representation for the calculation processes in signed languages (cf. Figures 5 & 6).

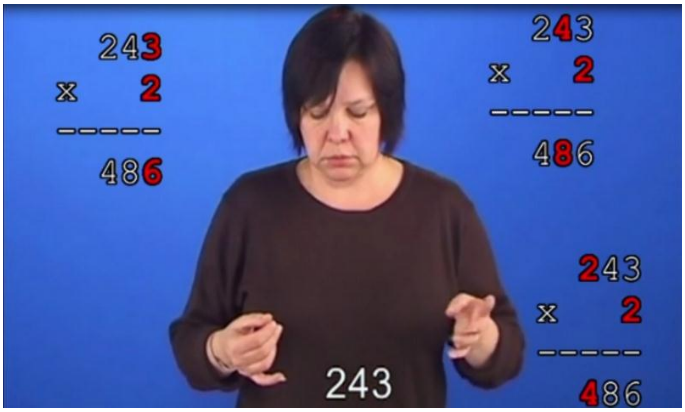

Figure 6: Visualising intermediary phases of the task 2 x 243. (Animation by Mikko Palo)

In our proposal the active/non-active state of the numeric entities in working memory is highlighted by visualising the referents in varying colours and sizes in the background of the video screen.
The corpus of mathematical discourse will be placed in Finnish SignWiki, a multifaceted open access dictionary of FinSL that uses crowdsourcing for collecting information. We hope that this non-language-dependent solution could be a way to encourage discussion and comparison of the calculation processes between users of other sign languages than FinSL, and promoting the multidimensional mathematical thinking of the Deaf people.

4. Acknowledgements

We thank Kone Foundation (Finland) for funding the Corpus and SignWiki Project 2013–2015.
We also thank Mr. Mikko Palo (Mediapalo Company) for the numeric animation of the data.

5. References

Bull, R. (2008). Deafness, Numerical Cognition, and Mathematics. In M. Marschark, P.C. Hauser (Eds.), *Deaf Cognition. Foundations and Outcomes*. Oxford: Oxford University Press, pp. 170--200.

Huovila, M., Seilola, I., Rainò, P. (2009). Visuaalista matematiikkaa. [Examples of Visual mathematics.] http://www.viivi.fi/osata_matematiikka/matematiikka.html. Retrieved 9.2.2014.

Hyde, M., Zevenbergen, R., Power, D. (2003). Deaf and hard of hearing students' performance on arithmetic word problems. *American Annals of the Deaf* 148 (1), pp. 56--64.

Foisack, E. (2003). *Döva barns begreppsbildning i matematik* [Mathematical conceptualisation by deaf children]. Malmö studies in educational sciences No. 7. Doctoral dissertation. School of Education, Malmö University.

Huovila, M., Rainò, P., Seilola, I. (2010). Visual calculation processes in Finnish Sign Language. Deafvoc. Conference on deaf education with a special focus on vocational education. Klagenfurt, Austria19.11.2010. http://www.deafvoc2.eu/materials/05_Visual_CalculationProcesses.ppt . Retrieved 9.2.2014.

Jantunen, T. (2003). *Johdatus suomalaisen viittomakielen rakenteeseen* [Introduction to the structure of Finnish sign language]. Helsinki: Finn Lectura.

Kelly, R.R., Lang, H.G., Mousley, K., Stacey, M.D. (2002). Deaf college students' comprehension of relational language in arithmetic compare problems. *Journal of Deaf Studies and Deaf Education* 8 (2), pp. 120--132.

Kelly, R.R., Lang, H.G., Pagliaro, C.M. (2003). Mathematics word problem solving for deaf students: A survey of practices in grades 6–12. *Journal of Deaf Studies and Deaf Education* 8 (2), pp. 104--119.

Liddell, S. K. (2003). *Grammar, gesture, and meaning in American Sign Language*. Cambridge: University Press.

Lukasczyk, U. (2008). *Sanottua, ajateltua, tehtyä. Referointi kolmessa suomalaisella viittomakielellä tuotetussa fiktiivisessä kertomuksessa* [Said, thought and done. References in three fictive stories produced in sign language]. MA Thesis in Pedagogics. Department of Teacher Education, University of Jyväskylä.

Neidle, C., Kegl, J., MacLaughlin, D., Bahan, B., Lee, R.G. (2001). *The syntax of American Sign Language*. Massachusetts: MIT Press.

Rainò, P., Seilola, I. (2008). Matemaattisen diskurssin kielioppia suomalaisessa viittomakielessä [Grammar of mathematical discourse in Finnish Sign Language]. In J. Keski-Levijoki (Ed.), Opettajankoulutus yhteisön luovana voimana: näkökulmia suomalaisesta viittomakielisestä ja viittomakielisten koulutuksesta [Teacher training as a creative force in community: Views of Finnish sign language training and education for sign language users]. *Journal of Teacher Researcher* 6, pp. 59--65.

Suvi — Suomalaisen viittomakielen verkkosanakirja 2003. [The on-line dictionary of Finnish Sign Language]. Helsinki: Finnish Association of the Deaf. http://suvi.viittomat.net. Retrieved 10.2.2014.

Sandler, W., Lillo-Martin, D. (2006). *Sign Language and linguistic universals*. Cambridge: Cambridge University Press.

Taub, S. F. (2001). *Language from the body. Iconicity and metaphor in American Sign Language*. Cambridge: Cambridge University Press.