# Polysigns and information density in teachers' gestures

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**Abstract**

Gesture goes hand in hand with speech and is a powerful communication device in expressing abstract concepts. In this paper, we analyse the spontaneous gestures of two teachers filmed teaching lessons on halving. Both speech and gesture were transcribed on *Elan,* and all the gestures were coded. We then focused on key gestures contributing to the mathematical concepts of halving discrete entities. We show how these gestures chain and provide multiple layers of information that embody and spatially represent the concept of halving. Simultaneously teachers use these representative gestures in interactive ways with children to enact the concept of halving. Gestures mediate the transition from concrete and personal symbolic processes to abstract mathematical concepts.

**Keywords:** gesture; learning; information density; multireferential gesture; polysign; mathematics

## Introduction

Gesture is a powerful communication device in spontaneous talk, narration, depiction, and in expressing spatial and abstract concepts. An increasing number of studies demonstrate the important role gestures play in cognition and learning (Roth, 2001), and there is now a substantial body of work on the effectiveness of using gesture in teaching mathematics (Gerofsky, 2010). Gesturing, by both teacher and learner, helps learners understand mathematical concepts (Broaders et al., 2007), and gestures are an integral part of learners' conceptual development (Goldin-Meadow, 2009). Teachers' gestures are therefore an important part of helping children learn, and the skill with which they use them may plays a role in how effective the teacher is. This study examines the kinds of gestures teachers use, their functions and the complex and multi-layered information they provide.

## Methodology

Data are drawn from a study of teachers' gestures in a private school in South Africa. We filmed two Grade One teachers each teaching a lesson on halving. The first teacher, Daisy, had 28 years of teaching experience. The second teacher, Chloe, was in her first year of teaching.

We transcribed the video recordings and annotated the gestures using *Elan* software (http://www.mpi.nl/tools/). We adapted Colletta et al.'s (2009) annotation scheme to analyse the speech and gesture of each teacher. Gestures were classified as: 'Deictic' which points to the referent present in the communication setting; 'Representational' which depicts or mimes a concrete referent, or symbolizes an abstract referent; 'Discursive,' i.e. cohesive gesture which aids in structuring speech; 'Framing,' i.e. expression of an emotion or a mental state that connotes the verbal content; 'Performative,' i.e. gestural production of a speech act; 'Interactive,' i.e. gestural production of a synchronization signal; and 'Word Searching' which indicates that the speaker is searching for a word or expression. We then analysed selected gestures examining the layers of semantic information they convey.

## Results

### Types of gestures

The teachers used four types of gestures during their lessons: representational, deictic, performative and discursive. Table 1 shows that both teachers had similar proportions of different gesture types. Overall, the most frequently used gestures were representational followed by deictic gestures.

Table1: Number and proportion of teachers' gesture types.

| Teacher | Repre-sentational | | Deictic | | Perfor-mative | | Discur-sive | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | # | % | # | % | # | % | # | % | |
| Daisy | 141 | 47 | 73 | 24 | 49 | 16 | 39 | 13 | 302 |
| Chloe | 88 | 45 | 43 | 22 | 42 | 22 | 22 | 11 | 195 |

### Representational gestures: functions

The teachers used representational gestures mainly to depict the mathematical content. The teachers used their representational gestures in four ways: to represent aspects

of the content of their speech, to gesture with the learner to represent aspects of the teacher's speech, to represent the content of the learner's speech while only the learner spoke, and as objects upon which the learners could gesture. Daisy and Chloe's learners sometimes gestured with their teachers' gestures, copying the teachers' gestures when the teacher spoke. Daisy instructed the learners to do so throughout the lesson. For example, when revising the concept of doubling, Daisy told the learners to hold up five fingers on their right hand and then on their left. As she said, "If I double five I take exactly the same amount and that makes ten," she got the learners to gesture this statement bringing each hand together so the thumbs touched, palm facing outwards with five fingers extended together. Chloe instructed her learners to do this only sporadically.

Twenty-one per cent of Daisy's and ten per cent of Chloe's representational gestures occurred with the learners gesturing the same gestures simultaneously. Daisy and Chloe also gestured silently with the learners' spoken answers. Daisy and Chloe's learners also gestured on their teachers' gestures. Daisy explicitly requested the learners to gesture on her gestures. For example, after Daisy got the learners to bring their hands together to illustrate doubling five to make ten, she then asked a number of learners to halve ten by moving their hand downwards in between her two hands to separate them. In the case of Chloe, the learners gestured spontaneously on their teacher's gestures as objects.

## Representational gestures and information density

We then focused on specific key gestures contributing to the mathematical concepts of halving discrete entities. At crucial moments during the lesson, Chloe and Daisy engaged in complex gesture production that involved several gesture phrases and several meanings, and led the children to perform these gestural schemes. To gain more insight into these gestures and the way they express mathematical concepts, we relied on Geneviève Calbris's "polysign" concept:

*"… one gesture may also represent several notions simultaneously because more than one of its components has an analogical link and, thus, it contains more than one gestural sign. In this case it is a polysign gesture."* (Calbris, 2011: 28).

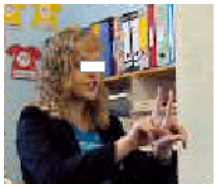
In Calbris' words, one gesture compounding a configuration and a movement can convey two distinctive meanings to act as a "bireferential gesture". However, a single hand configuration or a single hand movement can also convey more than one meaning and act as a "bireferential component". A bireferential gesture that compounds bireferential components is then called a "multireferential gesture". The most interesting property of such gesture is its ability to construct in space and movement complex referents, whether concrete or abstract:

*"In general, the meanings conveyed by the gestural components supplement one another to serve the multifaceted representation created by the gesture."* (Calbris, 2011: 190).

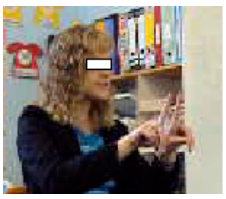
Polysigns are gesture forms that convey n>1 meanings. However, the meanings that can be attributed to a gesture stroke do not only depend on its intrinsic formal properties. In the context of a succession of gesture phrases, they also depend on their relation to other previous gestural episodes, as in the case of co-reference gestures. In a math class, showing two fingers can represent the number "two," but it can also, thanks to the repetition of gestures that show a various number of fingers, symbolize the abstract number "n".

We selected two "mathematical gestural schemes" (succession of gesture phrases linked to a specific mathematical object) out of Chloe and Daisy's gesture performance that illustrate both the compounding property of representational gesture put up by Calbris and the added information value due to the repetition of the same gesture scheme on various gesture strokes. Both mathematical schemes focus on the concept of halving.

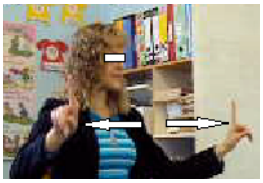
**Halving using the fingers** Chloe started her lesson by using a disk to introduce the concept of halving. Later, she used pieces of paper representing collections of black dots and asked the children to halve the number of dots on each paper using the same cutting technique. She ended this sequence with a generic example she gestured for the children. Our focus is on this example. First she brought both hands together at chest level with index extended while saying "if you have two" (fig.2a). While saying "and you halve it," she then used her right hand as a trencher in a rapid downward movement past the extended left index before returning to the previous location and configuration (fig.2b). Then she moved aside both extended fingers saying "you get" (fig.2c), lifted the left index up saying "one" (fig.2d) and finally the right index saying "one" again.



[2a] if you have two //

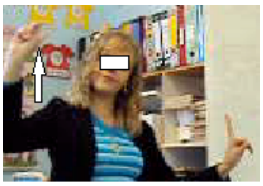


[2b] and you halve it //



[2c] you get //

[2d] one //



[2e] one

Figure 2: Halving using gesture.

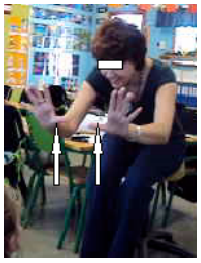
The first gesture [2a] represents number 2, thanks to the two extended fingers. The next gesture (the vertical trencher [2b]) symbolizes the concept of halving. However it occurs while the first gesture configuration remains, as shown in the return phase to the previous index location. At this stage, the gesture configuration compounds two meanings: dividing + number two. Gesture [2c] is very relevant here as it represents an operation (the movement of separating, dividing, analogy of halving in this case) with its start (number 2) and its result (number 1, represented by each extended finger). The two following gestures [2d] and [2e] maintain the new configuration while Chloe shows number 1 two times, the first time by lifting the left index, the second time by lifting the right index.

In this example, the operation of halving is still grounded on perception, but no longer on objectal experience. The information conveyed by the complete gestural scheme is complex and fully conveyed by the chaining of co-speech gestures. Overall, this gestural scheme represents a number, its two halves, and the halving operation itself. However, other gestural schemes can present a much higher information density.

**Halving using the child's gestures** Daisy introduces the concept of halving by recalling what doubling means using gestures and requesting children to gesture simultaneously. To symbolize ten as the outcome of doubling five, she got children to gesture this statement bringing each hand together so the thumbs touched, palm facing outwards with five fingers extended together. After several operations of the same kind, she shifted to halving by asking the learners what halving meant and then by asking a child in front of her to cut her fingers in half while presenting her two hands joined by the thumbs, all fingers extended (fig.3a). Then the child produced a rapid downward vertical trenching gesture that separated Daisy's both hands (fig.3b). Daisy lifted both hands, fingers still extended, while separating them (fig.3c). Then, while looking at another child and saying "I have five on this side", she moved her left hand forward with the five extended fingers (fig.3d), and then her right hand in the same configuration while saying "and five" (fig.3e).

[3a] cut my fingers in half //

[3b]



[3c]

[3d] I have five on this side

[3e] and five

Figure 3: Halving using gesture.

Like in Chloe's example, Daisy makes use of gestures to symbolize numbers and the operation of halving. However, unlike in Chloe's, the first gesture [3a] not only represents a number (10 in this case, supported by the ten extended fingers): the compound of both hands represents an abstract number which the learners know is the double of another one, thanks to the preceding activity. When the child separates both hands, this new cross-individual gestural configuration [3b] becomes saturated with meaning, as the trencher symbolizes halving, each set of five extended fingers represent 5 (half of 10), and each hand itself an abstract number corresponding to the half of the compound

of both hands. Gestures [3d] and [3e] convey the same type of double meaning: the actual number given by the number of fingers, and the abstract half concept. Her subsequent actions add relevance to our analysis: Daisy repeats the same gestural scheme with other numbers (6:3; 4:2, etc…) through rapid solicitations of one child after another.

The most striking fact here is both the high density of information expressed in gesture, and the poverty of information conveyed in the accompanying speech. Unlike in the first example, the chaining of gestures does not merely illustrate the speech content, rather, it conveys all relevant information and it displays an abstract knowledge of numbers that the learners contribute to expressing whereas the linguistic information remains far more basic and imprecise. In this example, the operation of halving, although grounded in perception, becomes more abstract, thanks to a specific use of gestures that – supposedly – brings the child to consider numbers not only as discrete entities in the surrounding world, but as abstract entities that combine together in multiple ways.

## Discussion

Daisy continuously represented mathematical concepts in gestures and she got the learners to do the same. With her gestures, she reconstructed key features of the collections of objects and the effects of the operation of halving on those collections. She did this by demonstrating what the effect of halving is on different numbers of entities represented by numbers of fingers by moving her hands apart to show halving and the outcome/answer. Daisy used her representational gestures interactively by getting the learners to gesture with her and by encouraging the learners to enact the mathematical operation of halving on her gestures. Daisy also got the learners to reconstruct collections of objects physically through gesturing with their fingers. When they shouted out an answer, she asked them to show her with gestures. She made the learners enact the operations as well. By getting the learners to recompose the collections of sets, both the originals and those submitted under the operation of halving using gesture, Daisy was able to evaluate the developing mathematical conceptions of the learners. She constantly performed evaluations by systematically asking learners individually to say and demonstrate their answers using gesture.

Chloe used gestures less frequently. Chloe enacted the mathematical operation of halving with her gestures both when introducing the concept of halving and at the third stage when learners halved numerals. However, in the first stage she twice used abstract gestures to signify halving quantities, but the gestures were not explicitly displayed. Chloe did not invite the learners to gesture with her or ask them to enact the operation of halving on her gestures. She only instructed the children once to gesture with her at the end of the lesson when halving the numeral 10. She also did not ask the children to use gestures to demonstrate their answers although some children did so spontaneously.

Both teachers' gestures conveyed complex information that expressed multiple levels of meaning in a single gestural scheme. Both teachers used "bireferential" and "multireferential" gestures to construct and represent complex abstract mathematical concepts. Allowing the children to perceive and enact these concepts with both objects and then gestures appeared to be an important process in understanding mathematical operations and the move to abstraction.

## Conclusions

The use of Calbris' (2011) notion of the polysign and "multireferential" gestures provides us with a way of accurately describing the kinds and complexity of information teachers provide through their gestures. In learning contexts, gestures and gestural schemes appear to play a key role in conveying conceptual information. Do all teachers use their gestures in the ways described above? To what extent do teachers maximize the meaning potential of gestures to be multireferential so to enhance learning and understanding? The concept of the polysign suggests a way of looking at how communicative skills and cognitive understanding are related and can work to enhance learning. Moreover, the use of representational polysigns in interactive ways with the active participation of children in the process of gesturing may be of professional significance to the kinds of pedagogical interventions teachers can make in the learning process.

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