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The processing of mathematical symbols in working memory

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This empirical study examines how different types of symbols, familiar and unfamiliar, are processed in working memory; phonologically and/or visuo-spatially.

Being able to communicate mathematics using both natural language (words) and the symbolic language is a key part of knowing and doing mathematics. This study is part of a larger ongoing project where we focus on the role of natural language for the learning of the symbolic language. In this project, we combine educational and cognitive perspectives to study both the underlying cognitive processes and the development of an understanding for mathematical symbols in an educational context. This presentation is delimited to a cognitive perspective on the processing of mathematical symbols. The purpose is to understand if and how different types of symbols are processed differently in working memory.

From a cognitive perspective, understanding of symbols can be characterized in terms of how information is encoded and stored in long term memory. This process is managed by working memory, which consists of three components; the central executive and two sub-systems (Baddeley & Hitch, 1974). The first sub-system is a phonological loop, dealing with information that is sound-based. The second is the visuo-spatial sketchpad, dealing with visual or spatial codes. Through letters and syllables, natural language is basically the encoding of sound, whereas mathematical symbols often are not, such as "+". However, through experience, you can develop phonological representation also for mathematical symbols, such as "plus" or "added" for the "+" symbol. When a symbol is only coded visuo-spatially, a student may need to shift frequently between phonological and visuo-spatial processing, such as when reading a text where a symbol appears in several places. This places great demands on the central executive in working memory, which is responsible for switching between tasks or strategies. This increased load would reduce the available cognitive resources, which in turn can affect the understanding that is created from the text. Educational empirical research also shows that when students read a mathematics text that presents something new for them, and which contains a mixture of symbols and natural language, their understanding of the content is worse, when compared with when they read a text that presents the same content but only using natural language (Österholm, 2006).

Method

To examine if and how different types of symbols are processed differently in working memory, we have started this ongoing study by comparing the processing of familiar mathematical symbols with unfamiliar symbols. We use made-up symbols as unfamiliar symbols, to ensure they are indeed unfamiliar for participants. To investigate whether symbols are processed phonologically or visuo-spatially, we use the dual-task paradigm (Guttentag, 1989). Within this methodological paradigm, participants perform two tasks simultaneously, a primary and a competitive (secondary) task. The goal is to find out what type of secondary task that disturb the participants' performance on the primary task the most (i.e., causing more errors). For example, if a secondary phonological task disturbs the performance on a primary task, this primary task is processed phonologically. In the present study, the primary task consists of a visual presentation of a set of 12 symbols, each shown for 4 seconds. In each set, every other symbol is familiar (mathematical) and every other is unfamiliar (made-up), that is, half of the symbols are familiar and half unfamiliar. The task for the participant is to remember and reproduce as many symbols as possible. The secondary phonological task is to repeat a specific word at constant pace. The secondary visuo-spatial task is to use your finger to tap, at a constant pace, on four spots in a square pattern. We also use a baseline setting, where the participants try to remember the symbols without any secondary task.

Tentative results

From the available analyses of four pilot participants, we can see that the secondary tasks indeed disturb the processing of the symbols. These participants worked with 10 sets in total. For all sets where there was a secondary task, the participants remembered 33-65 % of the symbols. For the sets without a secondary task (baseline), the participants remembered 50-92 % of the symbols. Among the symbols the participants remembered, with a secondary task or not, 50-60 % were mathematical. Also, for all but one of the sets, the participants remembered as many, or more, mathematical symbols than unfamiliar symbols. However, there is so far no clear pattern concerning differences between the results for the visuo-spatial and the phonological secondary task. The existing variation of performance on the primary task seems also to be more connected to different individuals. But we would like to stress the tentative nature of these results.

References

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