**More is bigger: Physical size in mental arithmetic**

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In our everyday lifes, we constantly add and subtract quantities, for example when checking whether we have enough money in our pocket to do the grocery's. How do we perform these mental calculations? One view contends that the process of mental arithmetic can be likened to amodal symbol manipulation, which meshes with the view that mathematics is entirely abstract. However, more and more evidence is showing that major parts of mathematics are in fact grounded in our everyday bodily experience (Lakoff & Núñez, 2000). Within the framework of embodied mathematics, mental arithmetic is thought to be based on the conceptual metaphor ARITHMETIC AS OBJECT COLLECTION. This metaphor states that our experiences of routine physical interactions with object collections map onto the relatively more abstract domains of addition and subtraction. On this view, addition is construed as putting a number of objects into a container, and subtraction, as removing a smaller collection from a larger collection (see Núñez, 2009).

Because "adding" physical objects necessarily leads to an increase in the size of a collection, this conceptual metaphor predicts that people should readily conceptualize addition as increased physical size and subtraction as decreased physical size. We tested this prediction with two drawing studies in which participants were given a simple mathematical problem to solve, such as "7-2=5" or "3+2=5". Participants were asked to replace each numeral by drawing circles on a sheet of paper (e.g., 5 circles to depict the number "5"). In Experiment 1, 203 participants drew circles for either addition or subtraction in a constrained setting, where the operator and equal sign were presented at a fixed position on the page. In Experiment 2, 306 participants drew the whole operation and were free to place it in any position on the page.

In both experiments, the circles that people generated in depictions of addition problems were larger than those circles produced in depictions of subtraction problems. Overall, these results lend support to the idea that mathematics is conceptually structured through physical experiences, and that mathematics is not in fact abstract, but associated with concrete notions such as physical size.

## References

Lakoff, G., & Núñez, R. (2000). *Where Mathematics Comes From: How the Embodied Mind Brings Mathematics into Being*. New York: Basic Books.

Núñez, R (2009). Numbers and arithmetic: Neither hardwired nor out there. *Biological Theory*, 4:1, 68-83.