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3. AN INDEXABLE AND INFORMATIVE COMMENTARY TITLE

For all authors of the commentary:

4. FULL COMMENTARY AUTHOR NAME(S)

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8. ONE HOME PAGE URL EACH (if applicable)

9. 60 word ABSTRACT

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11. ALPHABETICAL REFERENCE LIST (APA STANDARD)

The Role of the Brain in the Metaphorical Mathematical Cognition

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Abstract:

Rips, Bloomfield and Asmuth appear to discuss, and then dismiss with counterexamples, the brain-based theory of mathematical cognition given in Lakoff and Núñez (2000). Instead, they present another theory of their own that they correctly dismiss. Our theory is based on neural learning. They misrepresent our theory as being directly about real world experience and mappings directly from that experience.

Key Words: Embodied cognition; embodied mathematics; conceptual metaphor; metaphor; neural theory of metaphor; cognitive mathematics; neural theory of metaphor

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Rips, Bloomfield and Asmuth (hereafter, RBA) appear to discuss, and then dismiss with counterexamples, the brain-based theory of mathematical cognition given in Lakoff and Núñez (2000). In fact, they do not discuss our theory at all, but instead present another theory of their own that they correctly dismiss.

Our account is based on neural computation and neural learning, as discussed in (Feldman, 2006). The neural theory of conceptual metaphor and metaphor learning is discussed at length in (Lakoff and Johnson, 1999). On this account, the neural learning of primary metaphors is based on repeated correlated experiences that activate two different brain regions. The repetition of experience leads, via spreading activation and repeated synaptic strengthening along existing pathways, to the formation of neural circuitry linking the areas in an appropriate way so that the circuitry formed physically constitutes the conceptual metaphorical mappings that we observe in hundreds of cases in languages throughout the world. The mathematical cases are just special cases predicted from the general account.

We argue that, for arithmetic, there are four such primary metaphors that are neurally bound via best-fit principles of neural computation. The result is a metaphor system that yields the so-called “abstract” properties of arithmetic. Many of the properties of arithmetic arise from the metaphorical overlap of inferences, but some come from different metaphors in the system. We specifically show that not all the inferences can arise from metaphorical inferences based on any one area of experience.

Núñez and I argue further that infinite entities, such as infinite decimals or the set of all integers, or the set of all sums, arises from a quite general metaphor that characterizes infinite entities in general in all branches of mathematics. This Basic Metaphor of Infinity is simple and arises naturally from the neural theory of metaphor—outside of mathematics per se. It is based on Srinivas Narayanan’s neural computational theory of aspect in natural languages (Narayanan, 1997). In that theory, processes in the brain are computed via circuitry for what he calls “X-schemas,” short for executing schemas. Each process has an initial state, an iterated action (with no particular bound on the iteration), and an optional final state. Those without final states are called “imperfective” in linguistics — like walking. Those with final states—like walking 100 steps—are called “perfective.” Because of the overlap in the initial state and iteration, the activation of perfectives also activates the circuitry for imperfectives — over and over. The result is a neural metaphorical mapping in which unbounded iteration (unbounded infinite processes) are understood as having a metaphorical final state — an infinite entity, with special cases like the set of all integers and the set of all sums.

The central RBA argument is that the general properties of arithmetic cannot arise directly from real world experiences in themselves. We agree. It is the real world experiences as registered in human brains that results in learned circuitry that constitutes conceptual metaphors that yield the properties of arithmetic.

RBA do not argue against our theory. They act instead as if our theory were a version of the literal experience account that they correctly reject. Here is what they say (p. 27):

“According to Lakoff and Núñez (2000), the general properties of arithmetic depend upon mappings from everyday experience.”

That is a crucial misreading. According to us, the general properties of arithmetic depend up repeated correlated brain activations arising from everyday experiences of four basic kinds. Each correlated set of activations gives rise to a neural circuit that constitutes a primary conceptual metaphor. These fit together to give rise to the basic properties of arithmetic. There is all the difference in the world between our theory and their account of our theory.

RBA go on (p. 28):

“A key issue for the theory, though, is that everyday experience with physical objects, which provides the source domain for the metaphors, does not always exhibit the properties that these metaphors are supposed to supply. Closure under addition, for example, does not always hold for physical objects, as there are obvious restrictions on our ability to collect objects together.”

This is true of direct experience in the world, but not of the neural circuitry learned on the basis of repeated successful “small” cases of object collection, taking steps in a given direction, and so on. Our theory holds despite such physical limitations on large collections in the world.

RBA consistently misconstrue our theory as a version of the real world experience induction theory that they are arguing against.

I believe that Núñez and I got it right, not just for arithmetic, but for all the forms of higher mathematics we discuss. The general theory we give applies outside of mathematics per se, applies in languages and conceptual systems throughout the world, and also happens to work for mathematics as a special case. What we put forth is an explanatory theory that starts from the apparently inborn capacities for subitizing and baby arithmetic and adds neural learning theory, which gives rise to an account of the learning of primary metaphors in general, and primary conceptual metaphors for arithmetic in particular.

References

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