Western University
Scholarship@Western

Paediatrics Publications Paediatrics Department

9-1-2012

Introduction to the Special Section on "Numerical and Mathematical Processing"

Daniel Ansari
Western University, daniel.ansari@uwo.ca

Bert De Smedt
KU Leuven

Roland H. Grabner
ETH Zürich

Follow this and additional works at: https://ir.lib.uwo.ca/paedpub

Citation of this paper:
Ansari, Daniel; De Smedt, Bert; and Grabner, Roland H., "Introduction to the Special Section on "Numerical and Mathematical Processing"" (2012). *Paediatrics Publications*. 656.
https://ir.lib.uwo.ca/paedpub/656

MBE | Journal Name | mbe 1146 | Manuscript No. | B | Dispatch: July 2, 2012 | Author Received: | Journal: MBE | No of pages: 2 | CE: | TS: David

Introduction to the Special Section on "Numerical and Mathematical Processing"

Daniel Ansari[1], Bert De Smedt[2], and Roland H. Grabner[3]

Uncorrected Proofs

The processing of numerical information is a dominant feature of everyday life. Whether it is in the context of financial transactions, shopping for groceries, or gauging how many people are in a room, we are constantly using numerical information to guide our behavior and make decisions. On the other hand, number and mathematics constitute a crucial part of the curriculum during schooling. There is clear evidence that basic numerical and mathematical skills play a critical role in determining an individual's life success (Reyna, Nelson, Han, & Dieckmann, 2009). Furthermore, there is abundant evidence that low numeracy skills are associated with substantial costs to society at large (Butterworth, Varma, & Laurillard, 2011; Bynner & Parsons, 1997; Duncan et al., 2007).

Until recently research on the cognitive and neural foundations of numerical and mathematical skills was a relatively underinvestigated area of research, in particular when compared with the large body of research into the neurocognitive processes underlying the typical and atypical development of literacy and language competencies. However, this state of affairs has changed rapidly in the past 20 years, with much progress being made in understanding the evolutionary origins, ontogenetic foundations, and trajectories as well as neuronal correlates of number processing (for reviews see Ansari, 2008; Nieder & Dehaene, 2009; Piazza & Izard, 2009). The initial years of research into numerical and mathematical processing were characterized by basic research to answer question such as: What numerical competencies do nonhuman animals possess? When do numerical competencies emerge over developmental time? How are numerical symbols learnt? What brain regions are associated with arithmetic problem solving and how do brain activation patterns change over the course of learning and development? Many important answers to these questions have been provided through basic research that covers multiple levels of description ranging from single cell recordings to cross-cultural research with communities in remote locations.

In recent years, there have been increasing efforts to bridge between, on one hand, basic research on numerical and mathematical processing and, on the other hand, questions that arise from educational context such as: What are the predictors of individual differences in school-relevant measures of arithmetic achievement? What can we learn from empirical research on math skill development about the best way to diagnose and remediate children with mathematical difficulties, such as developmental dyscalculia?

The present special section in *Mind, Brain, and Education* builds on this momentum and includes four empirical research contributions that illustrate the potential of linking basic cognitive and neuroscience research with applied questions that are relevant to mathematics education.

In the domain of reading significant progress toward bridging between the research laboratory and the classroom was made when key foundational factors (such as phonological awareness) that predict typical and atypical reading development were identified, particularly, as this resulted in increased early diagnosis of children at risk of developing reading difficulties, where early interventions are appropriate (for a review see Gabrieli, 2009). In the domain of number processing, such low-level processing factors contributing to the development of higher level mathematical competencies that children are acquiring in the math classroom have recently been the focus of much research. For example, it has been shown that children's ability to indicate which of two Arabic digits or dot arrays is numerically larger correlates with and even predicts their scores on standardized tests of mathematical achievement (De Smedt, Verschaffel, & Ghesquiere, 2009; Halberda, Mazzocco, & Feigenson, 2008; Holloway & Ansari, 2009). Two of the contributions in this special section take this rapidly growing body of research forward in significant ways. Namely, in their article, Sasanguie,

[1]Numerical Cognition Laboratory, Department of Psychology, University of Western Ontario
[2]Faculty of Psychology and Educational Sciences, University of Leuven
[3]Institute for Behavioral Sciences, Swiss Federal Institute of Technology (ETH) Zurich, Switzerland Research

© 2012 the Authors

Van den Bussche, and Reynvoet present a longitudinal study to investigate which measures of basic number processing are the strongest predictors of later math achievement. Their findings show that nonsymbolic number estimation is the strongest predictor of math skills 1 year later, with the speed of comparing which of two numbers is numerically larger also accounting for some of the variance children's subsequent math performance.

Vanbinst, Ghesquière, and De Smedt further constrain these findings by investigating how measures of basic number processing are related to one specific school-taught mathematical skill, that is, elementary arithmetic and the strategies used to perform these calculations. Their data reveal that particularly children's symbolic magnitude processing, as measured by tasks that involve the comparison of Arabic digits, is related to their mathematical and arithmetical skills: Children with better access to numerical magnitude representations from symbolic digits retrieve more facts from their memory and are faster in executing various arithmetic strategies. They suggest that educators should particularly focus on connecting Arabic symbols to the quantities they represent. Furthermore, these data provide the first evidence to suggest that arithmetic fact retrieval frequency is related to basic, symbolic number processing.

The third contribution of this special section by Gabriel, Coché, Szucs, Carette, Rey, and Content moves on to educational intervention by investigating whether an intervention that focuses on the association between fractions and the magnitudes they represent improves children's understanding of fractions, a major stumbling block for many children in primary school. Their findings reveal that playing games, such as comparing and adding fractions and matching fractions to quantities, all of which foster the connection between fractions and their magnitudes, improved children's ability to estimate and compare fractions—again highlighting the fundamental role played by magnitude processing in the development of mathematical skills.

The final contribution of this special section bridges to the brain level using functional magnetic resonance imaging to examine basic neurocognitive processes related to mathematics learning in bilinguals. Specifically, Grabner, Saalbach, and Eckstein address the unresolved question of the sources of language-switching costs (i.e., poorer performance) in bilingual mathematics learning that arise when arithmetic problems are solved in a language different from the language of instruction. Two general cognitive mechanisms are discussed in the literature to account for these costs (Dehaene, Spelke, Pinel, Stanescu, & Tsivkin, 1999): they either reflect the need to translate arithmetic knowledge from the language of instruction into the language of application or they derive from additional mathematical information processing (e.g., calculation). The findings by Grabner, Saalbach, and Eckstein provide neurophysiological evidence in favor of the second mechanism and exemplify how neuroscience data can be used to achieve incremental insights into cognitive mechanisms of mathematics learning, whose understanding is of high educational relevance.

Taken together, the four contributions contained within this special section of *Mind, Brain, and Education* provide a diverse set of empirical research findings that, in the true spirit of the rapidly growing field of Mind, Brain, and Education, attempt to build bridges between basic research on the behavioral and neuronal mechanisms of numerical as well as mathematical processing and, on the other hand, educational questions.

Uncorrected Proofs

REFERENCES

Ansari, D. (2008). Effects of development and enculturation on number representation in the brain. *Nature Reviews Neuroscience*, *9*, 278–291.

Butterworth, B., Varma, S., & Laurillard, D. (2011). Dyscalculia: From brain to education. *Science*, *332*, 1049–1053.

Bynner, J., & Parsons, S. (1997). *Does numeracy matter*? London: The Basic Skills Agency.

De Smedt, B., Verschaffel, L., & Ghesquiere, P. (2009). The predictive value of numerical magnitude comparison for individual differences in mathematics achievement. *Journal of Experimental Child Psychology*, *103*, 469–479.

Dehaene, S., Spelke, E., Pinel, P., Stanescu, R., & Tsivkin, S. (1999). Sources of mathematical thinking: Behavioral and brain-imaging evidence. *Science*, *284*, 970–974.

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., et al. School readiness and later achievement. *Developmental Psychology*, *43*, 1428–1446.

Gabrieli, J. D. (2009). Dyslexia: A new synergy between education and cognitive neuroscience. *Science*, *325*, 280–283.

Halberda, J., Mazzocco, M. M., & Feigenson, L. (2008). Individual differences in non-verbal number acuity correlate with maths achievement. *Nature*, *455*, 665–668.

Holloway, I. D., & Ansari, D. (2009). Mapping numerical magnitudes onto symbols: The numerical distance effect and individual differences in children's mathematics achievement. *Journal of Experimental Child Psychology*, *103*, 17–29.

Nieder, A., & Dehaene, S. (2009). Representation of number in the brain. *Annual Review of Neuroscience*, *32*, 185–208.

Piazza, M., & Izard, V. (2009). How humans count: Numerosity and the parietal cortex. *Neuroscientist*, *15*, 261–273.

Reyna, V. F., Nelson, W. L., Han, P. K., & Dieckmann, N. F. (2009). How numeracy influences risk comprehension and medical decision making. *Psychological Bulletin*, *135*, 943–973.