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Inhibition of the whole number bias in decimal number comparison: A developmental negative priming study

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A major source of errors in decimal magnitude comparison tasks is the inappropriate application of whole number rules. Specifically, when comparing the magnitude of decimal numbers and the smallest number has the greatest number of digits after the decimal point (e.g., 0.9 vs. 0.476), using a property of whole numbers such as "the greater the number of digits, the greater its magnitude" may lead to erroneous answers. By using a negative priming paradigm, the current study aimed to determine whether the ability of seventh graders and adults to compare decimals where the smallest number has the greatest number of digits after the decimal point was partly rooted in the ability to inhibit the "the greater the number of digits, the greater its magnitude" misconception. We found that after participants needed to compare decimal numbers in which the smallest number has the greatest number of digits after the decimal point (e.g., 0.9 vs. 0.476), they were less efficient at comparing decimal numbers in which the largest number has the greatest number of digits after the decimal point (e.g., 0.826 vs. 0.3) than they were after comparing decimal numbers with the same number of digits after the decimal point (e.g., 0.981 vs. 0.444). The negative priming effects reported in seventh graders and adults suggest that

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inhibitory control is needed at all ages to avoid errors when comparing decimals where the smallest number has the greatest number of digits after the decimal point.

Introduction

Research in the field of numerical cognition has established domain-specific models of the development of numerical representations in children, whereby a full understanding of numbers builds on core systems dedicated to the processing of quantities (Feigenson, Dehaene, & Spelke, 2004). However, recent models have emphasized the role of more general cognitive abilities in this development such as the role of executive processes and inhibitory control in particular (e.g., Szucs, Devine, Soltesz, Nobes, & Gabriel, 2013). According to these models, inhibitory control abilities are necessary to reach a full understanding of discrete quantities by blocking interfering continuous dimensions of magnitude when judging the cardinal number of a set of objects. Although these processes can account for the development of the understanding of natural numbers, the question remains as to whether similar processes allow children to go beyond the set of whole numbers and extend their understanding to the sets of rational, irrational, and real numbers. The goal of the current study was to determine whether the understanding of rational numbers, especially decimal numbers, relies in part on inhibitory control.

A good understanding and mastery of rational numbers is critical because it constitutes one of the foundations of advanced mathematics (e.g., Siegler et al., 2012). However, children frequently struggle when learning about rational numbers (e.g., Vamvakoussi & Vosniadou, 2010) because the properties that govern rational numbers differ drastically from those of whole numbers. Therefore, prior knowledge and experience with whole numbers may interfere with attempts to learn about rational numbers (e.g., Ni & Zhou, 2005).

This interference has been referred to as the whole number bias (Ni & Zhou, 2005). Students may assume implicitly or explicitly that the features of whole numbers continue to apply to rational numbers, inducing systematic errors when rational numbers behave differently from whole numbers (e.g., Vamvakoussi & Vosniadou, 2010). Such errors may reflect conceptual difficulties with rational number representation (Vamvakoussi & Vosniadou, 2010). According to Vosniadou, Vamvakoussi, and Skopeliti (2008), children form an initial concept of numbers based on whole numbers during their preschool years. Because rational number information violates basic principles of the whole number concept, children must construct a new representation of rational numbers. Nonetheless, even after conceptual change has been achieved, the initial whole number representation continues to exist and influence rational number problem solving (e.g., Van Hoof, Lijnen, Verschaffel, & Van Dooren, 2013). Indeed, skilled adults still display the whole number bias in fraction comparison tasks when whole number representations interfere with rational number representations (Obsteiner, Van Dooren, Van Hoof, & Verschaffel, 2013). The whole number bias typically arises when the representation of the rational number magnitude is not sufficiently precise. In these instances, participants tend to rely on the more highly activated whole number representation to compare the magnitude of rational numbers (Alibali & Sidney, 2015).

Whereas many studies have reported whole number biases in the processing of fractions (e.g., Vamvakoussi, Van Dooren, & Verschaffel, 2012), few studies have investigated similar biases with decimal numbers. Decimal number comparison appears to be particularly difficult when the numbers being compared do not have the same number of decimal places (Roche, 2005). In this context, children tend to erroneously think that 0.476 is larger than 0.9 because 476 is larger than 9. These errors are likely the result of a whole number bias in decimals that consists of using a property of whole numbers, such as "the greater the number of digits, the greater its magnitude," to compare decimal numbers when the smallest number has the greatest number of digits after the decimal point (e.g.,