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Comparing the magnitude of two fractions with common components: Which representations are used by 10- and 12-year-olds?

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ABSTRACT

This study tested whether 10- and 12-year-olds who can correctly compare the magnitudes of fractions with common components access the magnitudes of the whole fractions rather than only compare the magnitudes of their components. Time for comparing two fractions was predicted by the numerical distance between the whole fractions, suggesting an access to their magnitude. In addition, we tested whether the relative magnitude of the denominator interferes with the processing of the fraction magnitude and, thus, needs to be inhibited. Response times were slower for fractions with common numerators than for fractions with common denominators, indicating an interference of the magnitude of the denominators with the selection of the larger fraction. A negative priming effect was shown for the comparison of natural numbers primed by fractions with common numerators, suggesting an inhibition of the selection of the larger denominator during the comparison of fractions. In conclusion, children who can correctly compare fractions with common components can access the magnitude of the whole fractions but remain sensitive to the interference of the relative magnitude of the denominators. This study highlights the fact that beyond the interference of natural number knowledge at the conceptual level (called the "whole number bias" by Ni & Zhou, 2005), children need to manage the interference of the magnitude of the denominators (Stroop-like effect).

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Introduction

Research on fractions has mainly investigated the development of the conceptual understanding of fractions and the obstacles to this learning. Yet, the representation of fraction magnitude has been tested by only a few studies, all of them testing adults. The current study aimed to test whether children who are able to correctly compare fractions with common denominators or common numerators access the magnitude of the whole fractions rather than just the magnitude of their components. We also tested whether the relative magnitude of the denominators interferes with the processing of the fraction magnitude by comparing performance on fractions with common numerators versus with common denominators. Moreover, the use of a priming paradigm allowed us to test whether the processing of the relative magnitude of the denominators, or the response associated with that comparison, is inhibited during the correct comparison of fractions.

Fractions denote rational numbers as the ratio of two integers. Therefore, they represent continuous magnitudes through the ratio of two discrete magnitudes. There is a wide consensus that one of the main sources of difficulty in learning fractions is the interference of previous counting and natural number knowledge. Children tend to interpret fractions by referring to this knowledge, which is called the "whole number bias" (Ni & Zhou, 2005). Because the properties of natural numbers differ from the properties of rational numbers, this bias interferes with fraction learning and leads to errors and misconceptions (e.g., Behr, Harel, Post, & Lesh, 1992; English & Halford, 1995; Grégoire & Meert, 2005; Hartnett & Gelman, 1998; Mack, 1993; Sophian, 1996; Stafylidou & Vosniadou, 2004). In Stafylidou and Vosniadou's (2004) study, 37.5% of the fifth-graders considered fractions as two independent natural numbers. This misconception led children to assume that the value of a fraction increases as the value of either the numerator or denominator increases or that the value of a fraction increases as the value of either the numerator or denominator decreases. The first conception is consistent with children's existing knowledge of numbers (i.e., knowledge of natural numbers). The second one is a transitional phase in the process of understanding fractions, a result of children's attempts to integrate the new information into their existing numerical knowledge. Stafylidou and Vosniadou underlined that students from 10 to 17 years of age gradually overcome this whole number bias and change their conceptual understanding of numbers before their understanding of fractions matches the scientific concept. For instance, students need to understand that numbers are not only made from counting and can be represented by a ratio between two numbers. In addition, they need to understand that each number has not one and only one successor (notion of density).

This study focused on the interference of the prior knowledge (i.e., the concept of natural numbers) in the acquisition of the concept of fraction. To our knowledge, no study has dealt with the mental representation activated when processing fractions in children who have enough knowledge of the concept of fractions to take into account the function of the natural numbers composing the fractions. In adults, the representation of the fraction magnitude has been investigated by using the numerical distance effect, which is the decrease in response times (RTs) with increases of the numerical distance between the numbers being compared (Moyer & Landauer, 1967). Bonato, Fabbri, Umiltà, and Zorzi (2007) asked adults to compare a target fraction with a fixed standard (1/5, 0.2, or 1). When the fixed standard was a fraction (i.e., 1/5), it always shared the numerator with the target fractions (e.g., 1/1, 1/2, 1/3). The distance between the denominators predicted RTs better than the distance between the whole fractions, suggesting that participants compared these components directly. This was also true in experiments where the fixed standard was not a fraction (i.e., 0.2 or 1). In that case, participants converted the standard into a fraction (e.g., 1/5, 5/5) to compare the components directly. Bonato and colleagues concluded that participants used a componential strategy (i.e., direct comparison of the denominators or numerators) to select the larger fraction.

Meert, Grégoire, and Noël (2009) asked adults to compare both fractions with common denominators (i.e., $a/x\_b/x$; e.g., 3/7_5/7) and fractions with common numerators (i.e., $x/a\_x/b$; e.g., 2/3_2/5) in the same experiment. In that context, RTs for fractions with common numerators (i.e., $x/a\_x/b$) were best predicted by the distance between the whole fractions, suggesting an access to the magnitude of the whole fractions. On the other hand, RTs for fractions with common denominators (i.e., $a/x\_b/x$)

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