Journal of Experimental Child Psychology 177 (2019) 152–165

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Patterning counts: Individual differences in children's calculation are uniquely predicted by sequence patterning

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ARTICLE INFO

Article history:
Received 26 October 2017
Revised 4 April 2018

Keywords:
Patterning
Arithmetic
Calculation
Symbolic magnitude processing
Children
Sequence patterns

ABSTRACT

Many studies have examined the cognitive determinants of children's calculation, yet the specific contribution of children's patterning abilities to calculation remains relatively unexplored. This study investigated whether children's ability to complete sequence patterns (i.e., add the missing element into 2–4–?–8) uniquely predicted individual differences in calculation and whether these associations differed depending on the type of stimuli in these sequence patterns (i.e., number, letter, time, or rotation). Participants were 65 children in first and second grade (M_{age} = 7.40 years, SD = 0.44). All children completed four tasks of sequence patterning: number, letter, time, and rotation. Calculation was measured via addition and subtraction tasks. We also measured cognitive determinants of individual differences in calculation—namely symbolic number comparison, motor processing speed, visuospatial working memory, and nonverbal IQ—to verify whether patterning predicted calculation when controlling for these additional measures. We observed significant relationships between the patterning dimensions and calculation, except for the rotation dimension. Follow-up regressions, controlling for the aforementioned cognitive determinants of calculation, revealed that the number and time dimensions were strong predictors of calculation, whereas the evidence for the letter dimension was only anecdotal and the evidence for the rotation dimension was nonexistent, suggesting some degree of specificity of different types of sequence patterning in predicting calculation. Symbolic magnitude processing remained a powerful unique correlate of calculation performance. These findings add to our understanding of

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https://doi.org/10.1016/j.jecp.2018.07.016

individual differences in calculation ability, such that sequence patterning could begin to be considered as one of the cognitive skills underlying calculation ability in young children.

Introduction

Many studies have examined the cognitive determinants of children's calculation, yet the specific role of children's (sequence) patterning remains relatively unexplored. Even though there have been suggestions of the links between patterns and mathematics (Papic, Mulligan, & Mitchelmore, 2011; Starkey, Klein, & Wakeley, 2004; Warren, Cooper, & Lamb, 2006), and patterning remains a component of children's education (Clements, Sarama, & Liu, 2008), research on patterning as one of the potential components of individual differences in mathematics development is lacking, with the existing literature on the origins of individual differences in mathematics being mainly focused on working memory or numerical processing (Peng, Namkung, Barnes, & Sun, 2016; Schneider et al., 2017; Vanbinst & De Smedt, 2016). While the existing body of patterning studies have almost exclusively examined the association between repeating patterns and calculation (Miller, Rittle-Johnson, Loehr, & Fyfe, 2016; Papic et al., 2011), sequence patterning is a relatively understudied type of patterning in comparison with repeating patterns. Therefore, the goal of the current study was to address this gap in the literature and examine the specific role of sequence patterning in elementary school children's calculation. In the remainder of the Introduction, we summarize the existing literature on relational thinking and patterning and present the aims of the current study.

Sequence patterns, compared with other types of patterning (e.g., repeating patterns), might be more critical to children's mathematical development when referring to counting sequences and number representation (e.g., counting; Thomas, Mulligan, & Goldin, 2002). The reason for this could be due to, for example, sequence patterns being related to relational thinking. Relational thinking, in the context of mathematical cognition, refers to the idea of inspecting the connections between two or more objects to solve a problem (Molina, Castro, & Ambrose, 2005). Although repeating patterns would also activate this type of thinking, sequence patterns are a more complex method by which to examine children's relational thinking. Taking relational thinking into account, as well as the complexity of sequence patterns compared with repeating patterns, sequence patterns are a potentially more beneficial type of patterning to examine compared with repeating patterning. Moreover, the idea of relational thinking has been applied in the domain of algebra (Carpenter, Levi, Franke, & Zeringue, 2005) and fraction learning (Empson, Levi, & Carpenter, 2011) and has been shown to be an important step in the development of arithmetic to algebraic learning (Napaphun, 2012). Sequence patterning, therefore, can be investigated with regard to its importance in mathematics competency, potentially through the mechanism of relational thinking.

Although relational thinking can be conceived as a potential general mechanism in sequence patterning, it is also possible that relational thinking is only involved in more specific associations with sequence patterning. For instance, a sequence pattern can be in numbers (i.e., 2–4–6–8) but can also be in letters (i.e., a–c–e–g). The question regarding relational thinking in sequence patterns, therefore, can also include the distinction between domain-specific sequence patterns (i.e., sequence patterns are related to mathematics only within some of these dimensions) and domain-general sequence patterns (i.e., every dimension of sequence patterning is related to mathematics). In examining distinct dimensions of sequence patterning and their relations to mathematics, the potential mechanism of relational thinking in the association between sequence patterning and mathematics can be examined as being either domain specific or domain general.

A pattern is any replicable regularity in which the items have relations to one another and are predictable (Economopoulos, 1998; Fyfe, McNeil, & Rittle-Johnson, 2015; Hendricks, Trueblood, & Pasnak, 2006; Papic et al., 2011). Patterns can be found in a variety of domains, including (but not limited to)