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Working memory predicts children's analogical reasoning

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ABSTRACT

Analogical reasoning is the cognitive skill of drawing relationships between representations, often between prior knowledge and new representations, that allows for bootstrapping cognitive and language development. Analogical reasoning proficiency develops substantially during childhood, although the mechanisms underlying this development have been debated, with developing cognitive resources as one proposed mechanism. We explored the role of executive function (EF) in supporting children's analogical reasoning development, with the goal of determining whether predicted aspects of EF were related to analogical development at the level of individual differences. We assessed 5- to 11-year-old children's working memory, inhibitory control, and cognitive flexibility using measures from the National Institutes of Health Toolbox Cognition battery. Individual differences in children's working memory best predicted performance on an analogical mapping task, even when controlling for age, suggesting a fundamental interrelationship between analogical reasoning and working memory development. These findings underscore the need to consider cognitive capacities in comprehensive theories of children's reasoning development.

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Introduction

Analogical reasoning—the cognitive process of drawing relationships between representations, often between prior knowledge and new representations—is a fundamental skill that develops dramatically in proficiency and resistance to distraction during childhood. Analogy plays a central role in higher-level cognition, and its ubiquitous and wide-ranging influence makes its developmental underpinnings essential to understanding human cognition more generally (Gentner, 2003; Hofstadter & Sander, 2013). Practically, analogical thinking is an important tool for learning. It enables children to, for example, extend existing knowledge to new contexts even if the representational systems look different. For instance, children might extend what they know about human energy needs (e.g., people need to eat for energy) to plants (e.g., plants likewise need energy input), although humans and plants differ in many respects. Building analogical reasoning skills is also a key objective for educational contexts, where children must build the skills to scaffold their own knowledge, to transfer it to new contexts, to explain new information, and to solve new problems, (Goldwater & Schalk, 2016; Richland & Simms, 2015). Understanding the mechanisms underlying analogical reasoning and development, therefore, is vital to identifying and intervening on points of dysfunction. In this study, we explored how one particular factor, executive function (EF), underlies the development of children's analogical reasoning.

Analogical reasoning and development

Formally, analogies are driven by alignment between systems of relations. Two situations are analogous if they share relational similarities regardless of other superficial properties or similarities. For example, plant stems are like drinking straws because they share functional and mechanistic relationships; both deliver liquid nourishment to a living organism, and both use differential pressure to move the liquid along the shaft. Children who understand how drinking straws work may be able to apply this knowledge to help them understand the less familiar domain of plant stems.

Performing analogical reasoning is not trivial. Assuming that a reasoner has recognized an opportunity for aligning the relationships in two or more analogues (e.g., the relationships between food and humans and between sunlight and plants)—no small feat in itself (Gick & Holyoak, 1980; Loewenstein, Thompson, & Gentner, 1999)—the reasoner must first encode the relational information from both analogues. These relational structures must be mentally maintained and manipulated to find correspondences between them (e.g., between the energy produced when a person metabolizes food and the energy produced when a plant photosynthesizes sunlight). If worthwhile correspondences are not initially found, the analogy must be discarded in favor of another or the representations must be flexibly modified to enable a better alignment (Kurtz, 2005; Yan, Forbus, & Gentner, 2003). For example, children might not initially see how food corresponds to sunlight because food is eaten, whereas sunlight is absorbed. However, this analogy becomes clear when children understand that both eating food and absorbing sunlight are intake processes. And all of this must take place while suppressing attention to irrelevant or extraneous information (Krawczyk et al., 2008).

This research explored whether EF resources can explain patterns of analogical reasoning for children between 5 and 11 years of age given analogy's high cognitive demands as described here. In particular, children's analogical reasoning improves along at least two key dimensions: the ability to resist perceptual distraction to prioritize relational information and the ability to handle and manipulate increasingly complex representations during alignment and mapping. We first describe this developmental trajectory and then explain the rationale for EF as an explanatory mechanism.

Object focus and relational shift

When children are given opportunities to engage in analogical reasoning, they often prioritize salient but nonrelational information over relational information (e.g., Daehler & Chen, 1993; Rattermann & Gentner, 1998; Thibaut, French, & Vezneva, 2010a). In particular, young children tend to rely on perceptually similar objects, which can detract from analogical reasoning performance if those object