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Children's attention to task-relevant information accounts for relations between language and spatial cognition

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ABSTRACT

Children's spatial language reliably predicts their spatial skills, but the nature of this relation is a source of debate. This investigation examined whether the mechanisms accounting for such relations are specific to language use or reflect a domain-general mechanism of selective attention. Experiment 1 examined whether 4-year-olds' spatial skills were predicted by their selective attention or their adaptive language use. Children completed (a) an attention task assessing attention to task-relevant color, size, and location cues; (b) a description task assessing adaptive language use to describe scenes varying in color, size, and location; and (c) three spatial tasks. There was correspondence between the cue types that children attended to and produced across description and attention tasks. Adaptive language use was predicted by both children's attention and task-related language production, suggesting that selective attention underlies skills in using language adaptively. After controlling for age, gender, receptive vocabulary, and adaptive language use, spatial skills were predicted by children's selective attention. The attention score predicted variance in spatial performance previously accounted for by adaptive language use. Experiment 2 followed up on the attention task (Experiment 2a) and description task (Experiment 2b) from Experiment 1 to assess whether performance in the tasks related to selective attention or task-specific demands. Performance in Experiments 2a and 2b paralleled that in Experiment 1, suggesting that the effects in Experiment 1 reflected children's selective attention skills. These findings show that selective attention is a central factor supporting

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spatial skill development that could account for many effects previously attributed to children's language use.

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Introduction

Spatial skills are foundational for higher cognition and encompass many behaviors, including perceiving and remembering locations, reasoning about object relations, maintaining orientation, and navigating through the environment. Early measures of spatial processing predict later math performance (Lauer & Lourenco, 2016; Verdine et al., 2014), and spatial skills in high school predict entry into science, technology, engineering, and math (STEM) fields (e.g., Wai, Lubinski, & Benbow, 2009). Individual and sex differences in spatial cognition arise early in development (e.g., Linn & Petersen, 1985; Pruden, Levine, & Huttenlocher, 2011), leading to cascading individual differences in prerequisite skills necessary for later life achievement. Despite the importance of spatial skills, there is limited understanding of the mechanisms underlying spatial development, inhibiting our abilities to promote spatial skills.

Multiple studies have found language effects on different spatial skills during early childhood (i.e., 3–6 years of age), including searching after disorientation (Hermer-Vazquez, Moffet, & Munkholm, 2001), forming analogies among object relations (Loewenstein & Gentner, 2005), remembering relations among object parts (Dessalegn & Landau, 2008, 2013), mental rotation (Pruden et al., 2011), and reference frame selection in recall (Miller, Patterson, & Simmering, 2016). In interpreting these effects, theorists often propose that language development has a causal impact on spatial cognition through verbal encoding. Some theorists propose that language is essential for spatial development, fundamentally changing our spatial processing (e.g., Shusterman & Spelke, 2005). More commonly, other theorists argue that language facilitates spatial cognition because it directs attention and enhances encoding of relevant spatial information (e.g., Pruden et al., 2011). In this article, we present an alternative perspective suggesting that verbal encoding does not play a central role in spatial cognition. Rather, children's basic attention skills are a central factor supporting both their language use and their spatial skills.

Most research on language and spatial skills is consistent with multiple explanations because the studies were not designed to differentiate these alternatives. Prior investigations have typically been correlational, assessing whether children's production of specific terms predicts their spatial performance, or experimental, providing children with specific words to enhance their spatial performance. In both study types, the language measures or manipulations could relate to children's selective attention to relevant information within the tasks rather than specifically relating to their language use. Selective attention is the ability to filter irrelevant information and focus on relevant information. Selective attention improves during early childhood (e.g., DeMarie-Dreblow & Miller, 1988), the same time that spatial skills are improving (Vasilyeva & Lourenco, 2010) and the age range when many of the links to language have been shown. There has been limited direct investigation of selective attention in relation to effects of language on spatial skills, making it difficult to evaluate possible underlying causal relations. The current research took a step in this direction by examining individual differences in both language use and selective attention as they relate to young children's spatial performance.

Investigations of language effects on spatial skills

One way in which researchers have shown the effect of language is through testing children's production of spatial words and how that predicts spatial performance. Children's spatial word production (e.g., "left/right," "by/next," "middle") predicts performance on tasks involving those spatial relations (Hermer-Vazquez et al., 2001; Miller et al., 2016; Simms & Gentner, 2008). Similarly, children

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