Finding the *middle*: Spatial language facilitates spatial reasoning

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Spatial relations are fundamental to spatial thinking. Understanding concepts like *left* and *right*, for example, facilitate navigation. *Parallel* and *perpendicular* are spatial relations that are unavoidable in geometry and engineering. However, relational concepts can be difficult for young children (Gentner & Rattermann, 1991), and some relations are more challenging than others. For example, young children have difficulty with the spatial relation *midpoint* (i.e., *middle*) (MacDonald, Spetch, Kelly, & Cheng, 2004; Spetch & Parent, 2006; but see Uttal, Sandstrom, & Newcombe, 2006). Understanding *midpoint* is important for other science and math concepts like *balance*, *half*, and *bisect*, to name a few. Compared to some of the spatial relations that young children understand, like *on*, *in*, or *under*, *midpoint* is a complex relation. It encodes location relative to more than one entity (e.g., in the middle of the sofa and the chair). *Midpoint* is also unusual because it integrates both qualitative (i.e., *between*) and quantitative spatial information (e.g., *three inches from both entities*).

When do children begin to understand the *midpoint* relation, and what helps them do so? A previous study on *midpoint* found that on a challenging *midpoint* search task, the only children who succeeded were those who also spontaneously described the location as "in the middle" (MacDonald et al., 2004). This is consistent with other research showing that spatial language is related to and facilitates spatial reasoning (Dessalegn & Landau, 2008; Hermer-Vazquez, Moffet, & Munkholm, 2001; Loewenstein & Gentner, 2005; Pruden, Levine, & Huttenlocher, 2010). Thus, in a series of studies we explore the relationship between spatial language and *midpoint* understanding. In all studies, we use a Midpoint Search Task to evaluate children's understanding of the *midpoint* relation. The task involves hiding a small treasure box for children to find. The treasure box is always hidden exactly in the middle of two flags, and the flags may be placed in different locations and at different distances from each other (see Figure 1).

Figure 1. Midpoint Search Task Apparatus

In our first study (Simms & Gentner, 2008), we administered the Midpoint Search Task to 3-, 4-, and 5-year-olds. We also assessed children's comprehension and production of the words *middle* and *between*, along with some other spatial terms. In general, children's ability to encode *midpoint* improved with age, $F(2,59) = 13.27$, $p < .001$, especially between 3- and 4-years-old, $p < .001$. (Figure 2). Even more striking was that children's knowledge of the words *middle* and *between* predicted their success on the search task, beyond the improvements seen with age, $\beta = 0.27$, $p < .05$. Also, as MacDonald and colleagues (2004) found, children who produced the words *middle* or *between* during the task outperformed children who did not (Figure 3).

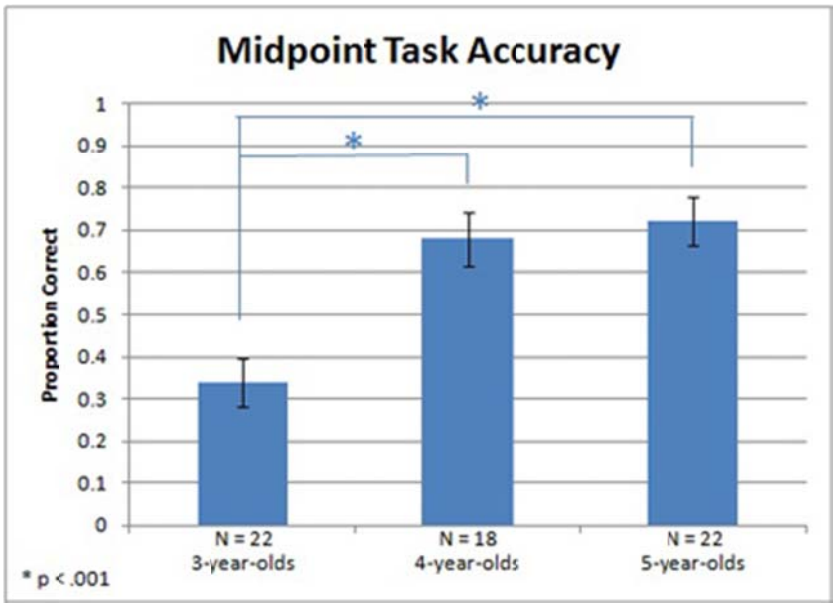

Figure 2. Children's accuracy on Midpoint Search Task. Children's performance improved with age.

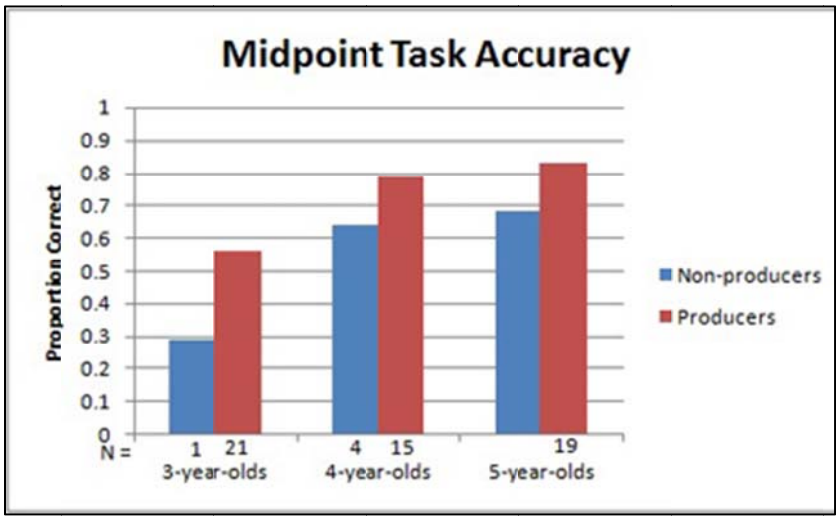

Figure 3. Children's accuracy on Midpoint Search Task. Children who produced words middle *or* between *outperformed children who did not.*

In our second study, we asked whether we could improve the youngest children's performance on the Midpoint Search Task by using the word *middle* during the task. For a new group of 3-

year-olds, when children found the treasure box on each trial, the experimenter told them that they had found it, "right in the middle of the two flags". The use of the word *middle* during the task significantly improved children's performance on the challenging search task, $F(1,44) = 4.12$, $p < .05$. (Figure 4).

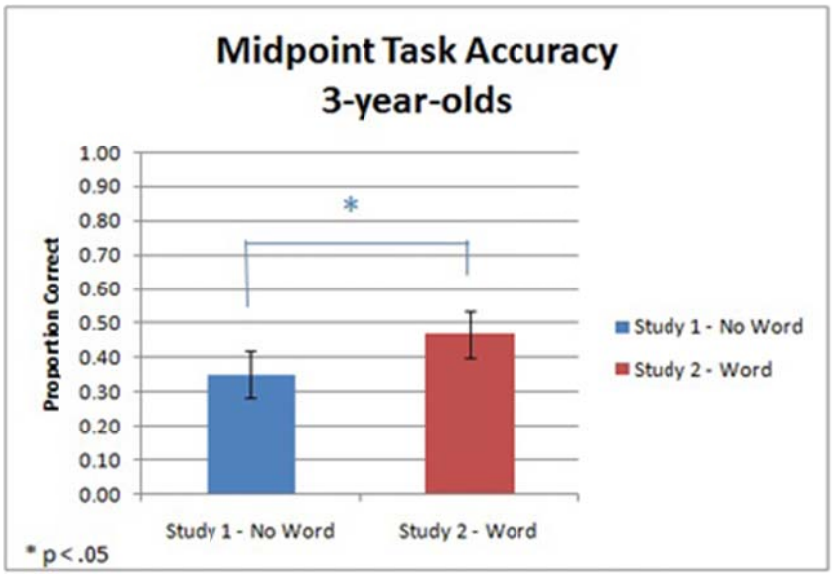

Figure 4. Children's accuracy on Midpoint Search Task. Hearing the word middle *improved children's performance.*

In two ongoing studies, we are further exploring how relational language can benefit young children's reasoning about the *midpoint* relation. If, as our first study suggests, the ability to label a spatial relation enables children to better reason about that relation (recall that children who produced the words *middle* or *between* were more successful on the search task), then teaching children a label for the *midpoint* (i.e., *middle*) ahead of time should also facilitate their performance. Thus, in one ongoing study, we are teaching children about the *midpoint* relation, with or without using the label *middle*, to see whether children who have learned the label are better able to encode the *midpoint* on the Midpoint Search Task. Preliminary results suggest that children are indeed more successful if they have learned the label *middle*.

In a second ongoing study, we compare the efficacy of labels to another tool that has been shown to help children reason about spatial relations: maps (Uttal, Fisher, & Taylor, 2006). Maps differ from labels in important ways (Davies & Uttal, 2007). Labels convey spatial information *sequentially*, map *arbitrarily* to spatial concepts, and usually represent only *qualitative* information. In contrast, maps convey information about multiple spatial relations *simultaneously*, map fairly *veridically* to spatial relations, and represent both *qualitative and quantitative* information. Accordingly, maps could be a particularly effective way to communicate the unique and challenging aspects of *midpoint*. Thus, the current study explores the relative effectiveness of labels and maps, separately and in combination, as tools to communicate spatial relational information to preschoolers. Preliminary results suggest, consistent with prior findings, that hearing a label during the search task improves their performance, even after the label is no longer used. Surprisingly, however, the results so far do not show a benefit for seeing a map. Though children this age have been shown to successfully use maps (e.g., Bluestein & Acredolo, 1979), they may not be well-suited to communicate spatial information for this task at these ages.

These studies add to a growing literature demonstrating the power of language as a tool to enhance children's spatial reasoning. Future research should begin to address the conditions under which spatial language are most beneficial and translate this research into methods that can be used by parents and educators to help children become effective spatial reasoners.

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