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Language supports young children's use of spatial relations to remember locations

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ABSTRACT

Two experiments investigated the role of language in children's spatial recall performance. In particular, we assessed whether selecting an intrinsic reference frame could be improved through verbal encoding. Selecting an intrinsic reference frame requires remembering locations relative to nearby objects independent of one's body (egocentric) or distal environmental (allocentric) cues, and does not reliably occur in children under 5 years of age (Nardini, Burgess, Breckenridge, & Atkinson, 2006). The current studies tested the relation between spatial language and 4-year-olds' selection of an intrinsic reference frame in spatial recall. Experiment 1 showed that providing 4-year-olds with location-descriptive cues during (Exp. 1a) or before (Exp. 1b) the recall task improved performance both overall and specifically on trials relying most on an intrinsic reference frame. Additionally, children's recall performance was predicted by their verbal descriptions of the task space (Exp. 1a control condition). Non-verbally highlighting relations among objects during the recall task (Exp. 2) supported children's performance relative to the control condition, but significantly less than the location-descriptive cues. These results suggest that the ability to verbally represent relations is a potential mechanism that could account for developmental changes in the selection of an intrinsic reference frame during spatial recall.

1. Introduction

Language is a tool that can augment cognition, with effects demonstrated in areas such as numerical representation (e.g., Miura, Kim, Chang, & Okamoto, 1988), categorization (e.g., Bowerman & Choi, 2003), analogical reasoning (e.g., Gentner, 2003), and spatial reasoning (e.g., Haun, Rapold, Janzen, & Levinson, 2011; Pyers, Shusterman, Senghas, Spelke, & Emmorey, 2010). Recently, there has been increased interest in understanding relations between language and spatial cognition over development. Research indicates that providing task-relevant verbal cues while children perform spatial tasks can bolster children's performance (Dessalegn & Landau, 2008, 2013; Loewenstein & Gentner, 2005; Shusterman, Lee, & Spelke, 2011) and that children's spatial language production abilities predict their spatial skills (Hermer-Vazquez, Moffet, & Munkholm, 2001; Pruden, Levine, & Huttenlocher, 2011). However, the specific way in which language relates to spatial cognition is not universally agreed upon (e.g., Nardini, Burgess, Breckenridge, & Atkinson, 2006; Ratliff & Newcombe, 2008), and this relation has previously only been tested in a limited range of spatial tasks. In this paper, we extend the literature by investigating the role of language in a type of spatial skill that has been given little prior consideration: children's selection among spatial reference frames to recall object locations, with a focus on the intrinsic reference frame.

Providing spatial language in the context of spatial tasks can promote preschool-aged children's spatial performance (e.g., Dessalegn & Landau, 2008, 2013; Loewenstein & Gentner, 2005; Shusterman et al., 2011). Loewenstein and Gentner (2005) showed that providing children with spatial terms such as 'top' and 'middle' during or just prior to a relational mapping task increased children's performance. Dessalegn and Landau (2008) found similar effects with 4-year-olds using a different type of spatial task, the feature binding task, which assessed memory for visual feature conjunctions. Providing children with spatial terms specifying the location of one colored feature relative to the other (e.g., "the red is on the left") improved their performance in remembering the bindings between the features. These effects are not limited to terms that describe spatial relations. Language can also highlight pragmatic information about the relevance of cues for solving spatial tasks. For example, Shusterman et al. (2011) tested 4-year-old children in a disorientation search task that requires integration of

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featural cues (i.e., a uniquely-colored wall in the task space) with geometry to successfully reorient. In this task, children typically do not use features until 6 years of age (Hermer-Vazquez et al., 2001; but see Cheng & Newcombe, 2005), however Shusterman et al. found that telling participants "the red wall can help you find the sticker" helped younger children solve the task.

Additionally, children's abilities to produce spatial language predicts their spatial skills (Hermer-Vazquez et al., 2001; Pruden et al., 2011; Simms & Gentner, 2008). Children's production of words such as 'left', 'right', and 'middle' was positively associated with performance on spatial tasks that depend on these spatial relations (Hermer-Vazquez et al., 2001; Simms & Gentner, 2008). Furthermore, the total number of spatial words that children produced in a free-play setting correlated longitudinally with their spatial skills across a variety of spatial measures (Pruden et al., 2011). These two types of results—those that show language input boosts performance and those that show correlations between spatial word production and spatial skills—have been interpreted as evidence that spatial language enables children to verbally encode task-relevant spatial information, thereby improving spatial task performance.

Whereas language has been shown to enhance children's performance across some spatial tasks, limited attention has been given to the effects of language on reference frame selection. The flexible use of reference frames in spatial recall develops throughout early childhood (Nardini et al., 2006), in parallel with improvements on the disorientation search task (Hermer-Vazquez et al., 2001). By 2 years of age, children can select among egocentric or allocentric reference frames, remembering object locations relative to themselves or environmental cues (e.g., Acredolo, 1978; Bai & Bertenthal, 1992; Newcombe, Huttenlocher, Drummey, & Wiley, 1998). However, children struggle to utilize one particular type of allocentric reference frame, an intrinsic reference frame, until 5–6 years of age (Nardini et al., 2006). Selecting an intrinsic reference frame requires using the configuration among objects to anchor memory without relying on the body or distal environmental cues. Investigating the role of language in children's intrinsic reference frame selection is of particular interest because preliminary evidence suggested language may not contribute to the development of this spatial ability (Nardini et al., 2006), even though this ability shows a similar developmental trajectory to other spatial abilities that relate to language (Hermer-Vazquez et al., 2001).

To assess 3- to 6-year-old children's use of an intrinsic reference frame in recall, Nardini et al. (2006) adapted a task by Simons and Wang (1998). On each trial, a toy was hidden under one of thirteen cups arranged on a table, with unique landmarks along two edges of the table. On all trials the intrinsic reference frame was available and constant, as children could use the stable configuration of objects (i.e., cups and landmarks) within the array to remember the location. Across trials the alignment of the other reference frames varied through changes in the child's position (disrupting egocentric alignment) and/or changes in the array's position (disrupting room-centered alignment). Children performed best when all three reference frames (intrinsic, egocentric, room-centered) maintained alignment from hiding to search, and worst when the three were misaligned—trials that relied most heavily on the intrinsic reference frame. Additionally, only 5- and 6-year-olds performed significantly above chance on trials in which the array rotated between hiding and search, suggesting that children's reliance on the intrinsic reference frame is not well developed before 5 years of age.

Although language was not the focus of their study, Nardini et al. (2006) also assessed whether verbal encoding during the task contributed to this developmental change. They tested verbal encoding during one "surprise" trial on which, following the delay, the experimenter asked the child to describe the toy's location. The location was selected to be relatively easy to describe, as it was directly between two landmarks. Children's use of landmarks to describe the location increased with age: 0% of 3-year-olds, 19% of 4-year-olds, 29% of 5-year-olds, and 71% of 6-year-olds. Of most interest was performance by 5-year-olds, as only a few of them described the landmarks, but as a group they performed above chance on the recall task (this effect held even when analyzing only children who did not use verbal descriptions). The authors concluded that verbal encoding was not necessary for the development of reference frame selection, but noted that a single trial was not a comprehensive method for testing whether language could support intrinsic reference frame selection.

In this paper, we investigated the influence of spatial language on children's use of an intrinsic reference frame during recall. We extend the literature not only by testing the effects of language on a spatial skill that has received limited attention, but also by contributing to the debate on the effects of language on spatial skills more generally. Some researchers have theorized that language is necessary for the development of advanced spatial cognitive skills (e.g., Hermer-Vazquez et al., 2001; Pyers et al., 2010) while other theorists have argued against a central role for language (Learmonth, Newcombe, Sheridan, & Jones, 2008; Nardini et al., 2006; Ratliff & Newcombe, 2008). Proponents of these contrasting perspectives have approached their research using different methodologies. The former perspective has provided evidence through giving children verbal cues during spatial tasks (e.g., Shusterman et al., 2011) and through assessing whether production of spatial terms outside of the spatial task context correlates with spatial performance (e.g., Hermer-Vazquez et al., 2001). The latter perspective has tested children at a particular age level who are believed to lack the necessary words to solve the spatial tasks or who show no evidence of verbal encoding during the task (Learmonth et al., 2008; Nardini et al., 2006). We combine these approaches by providing children with verbal cues to support selection of an intrinsic reference frame in recall (similar to the former perspective) and by assessing children's spatial language production to describe the spatial task space (similar to the latter perspective).

We used a recall task similar to Nardini et al. (2006) to evaluate children's reference frame selection and spatial descriptions. We tested 4-year-olds because this age was just prior to the reliable use of the intrinsic reference frame in Nardini et al.'s study and because multiple studies have shown relations between spatial skills and language at 4 years of age (Dessalegn & Landau, 2008, 2013; Loewenstein & Gentner, 2005; Pruden et al., 2011; Shusterman et al., 2011). Experiment 1 tested whether verbal encoding of spatial relations among objects contributed to children's selection of an intrinsic reference frame during recall. To address this question, Experiment 1a examined: (1) whether providing children with verbal cues that specified relations among objects on the testing array helped children select an intrinsic reference frame; and (2) whether children's abilities to produce accurate verbal descriptions of spatial relations predicted recall performance on trials depending on the intrinsic reference frame, in the absence of verbal cues from the experimenter. Experiment 1b tested the effect of providing verbal cues before (rather than during) the recall task. Experiment 2 investigated whether visual cues provided comparable support to children's performance as the verbal cues in Experiment 1a.

2. Experiment 1a

Experiment 1a tested whether verbal encoding of spatial locations could support children's selection of an intrinsic reference frame during recall. We tested this question in three ways with