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Aligning body and world: Stable reference frames improve young children's search for hidden objects

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ABSTRACT

This study investigated how young children's increasingly flexible use of spatial reference frames enables accurate search for hidden objects by using a task that 3-year-olds have been shown to perform with great accuracy and 2-year-olds have been shown to perform inaccurately. Children watched as an object was rolled down a ramp, behind a panel of doors, and stopped at a barrier visible above the doors. In two experiments, we gave 2- and 2.5-year-olds a strong reference frame by increasing the relative salience and stability of the barrier. In Experiment 1, 2.5-year-olds performed at above-chance levels with the more salient barrier. In Experiment 2, we highlighted the stability of the barrier (or ramp) by maximizing the spatial extent of each reference frame across the first four training trials. Children who were given a stable barrier (and moving ramp) during these initial trials performed at above-chance levels and significantly better than children who were given a stable ramp (and moving barrier). This work highlights that factors central to spatial cognition and motor planning—aligning egocentric and object-centered reference frames—play a role in the ramp task during this transitional phase in development.

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Introduction

Recent studies have revealed something quite striking: Older children sometimes fail to show competencies that infants have been thought to have. For example, researchers presented 2- and 3-year-olds with a ball that rolled down a ramp (Berthier, DeBlois, Poirier, Novak, & Clifton, 2000). The ball

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went behind an occluder with four doors and stopped at a barrier, visible above the occluder. The barrier could be placed beside any of the doors. Berthier and colleagues found that 2- and 2.5-year-olds were not able to select the correct door when asked to find the ball in this "ramp task." In fact, only 3 of 16 2.5-year-olds performed at above-chance levels. The 3-year-olds were able to reliably choose the correct door at above-chance levels. This is surprising because infants in a related violation-of-expectancy task appear to understand that solid objects behind an occluder stop at solid barriers (see Spelke, Breinlinger, Macomber, & Jacobson, 1992). We are left to wonder how infants can demonstrate an understanding of hidden objects and solid barriers, whereas toddlers cannot.

One possibility is that this discrepancy reflects methodological issues. In particular, tasks used with infants rely on looking behaviors, whereas those with toddlers require reaching responses. It is possible that the added demands of generating a reaching response make the ramp task quite challenging for toddlers. In fact, toddlers have been shown to perform as infants do in a looking version of this task (Hood, Cole Davies, & Dias, 2003). Although this explains differences between infants' and toddlers' performances, such demands do not explain why 2-year-olds—but not 3-year-olds—have difficulty in the reaching task. To understand why 3-year-olds can solve this task, whereas 2-year-olds cannot, we must examine the changes between 2 and 3 years of age that enable successful performance.

Certainly, part of the answer must lie in the complex processes involved in reaching for a hidden object. For instance, in some versions of the ramp task, children must get up off a chair and walk to a table before reaching for a specific door (e.g., Perry, Smith, & Hockema, 2008). This requires coordinating movements of the body—eyes, head, arms, and legs—with visuospatial information in the task space specifying the location of the target door (Keen & Berthier, 2004). More specifically, as children approach the ramp, get close, and then ultimately reach for a door, they must track where they are relative to the ramp and barrier. Note that children face related challenges in tasks where they sit in a chair and the ramp is moved toward them (e.g., Berthier et al., 2000). Although such tasks do not require children to walk, children must still update their position relative to the ramp as it is moved toward them.

Seemingly, then, the ramp task sets up a challenging visuospatial coordination problem because the spatial frame of reference on which children should rely—the barrier—is small and flimsy and moves from trial to trial. It is well known that young children rely on large stable landmarks to establish their orientation in space (Learmonth, Newcombe, & Huttenlocher, 2001; Newcombe & Huttenlocher, 2000). Thus, as children prepare to reach toward the ramp, they are most likely to orient relative to the occluder affixed to the ramp. Young children's perseverative reaching in the ramp task is consistent with this idea. Specifically, children under 3 years of age have a strong tendency to open the same door they opened on the previous trial (Berthier et al., 2000). Indeed, considered together, it appears that two things conspire against young children in the ramp task. First, the barrier is small and moves from trial to trial and, therefore, is a poor spatial reference frame. Second, young children have a strong tendency to reach repeatedly to the same location in space (see Schutte, Spencer, & Schöner, 2003; Spencer, Smith, & Thelen, 2001).

If these two factors conspire against 2-year-olds in the ramp task, what changes around 3 years of age to enable better performance? Research in spatial cognition suggests that there are dramatic changes in how young children use spatial reference frames between 1 and 3 years of age. Evidence from reaching tasks indicates that children initially encode locations egocentrically (e.g., Acredelo, 1978). By 16 months of age, children can use a visible spatial reference frame—for example, the edges of a sandbox—to encode the location of a hidden object (Huttenlocher, Newcombe, & Sandberg, 1994), but it is not until 22 months of age that children encode the position of an object relative to external landmarks even when moved from one side of the sandbox to another (Newcombe, Huttenlocher, Drummey, & Wiley, 1998). Beyond 22 months of age, use of object-centered coding is still relatively inflexible. For instance, when 2.5-year-olds are shown a hiding event in a small dollhouse and are then asked to find a toy hidden in an analogous place in a larger scale model, they typically search either randomly or perseveratively, whereas 3-year-olds succeed (DeLoache, 1987; DeLoache, 1989). If, however, the dollhouses are similar in size and aligned in orientation, 2.5-year-olds succeed, suggesting that the ability to align reference frames may play a role in this task (DeLoache, 1987; DeLoache, 1989). Beyond 3 years of age, use of spatial reference frames continues to change. It is not until around 4 years of age, for example, that children start using more subtle spatial reference frames such as axes of symmetry in adult-like ways (Schutte & Spencer, in press).