The Development of Spatial Cognition During Childhood: Extending Understanding of Perception, Memory, Language, Maps, and Gestures

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Symposium Overview

Understanding the development of spatial cognition during childhood is important. Paying close attention to development provides a lens through with to explore mechanisms that underlie stability and change in perception, memory, language, and symbolic understanding over time. This symposium, moderated by Alycia Hund, includes four talks highlighting tight links between spatial perception of midline and memory for nearby targets during early childhood explicated through dynamic systems theory, specifying the development of spatial language (especially *middle* and *between*) during early childhood by focusing on the role of scaffolding interactions, exploring links between spatial language, maps, and midpoint search strategies during early childhood, and explicating spatial thinking during childhood by integrating maps, words, and gestures. The symposium concludes with a discussion of common themes, including how children perceive, remember, talk about, and gesture about *middle* and other spatial relations.

Spatial Perception and Working Memory

Perception and cognition are inextricably intertwined. This interaction is evident in the development of spatial memory. Early in development there is a transition in memory biases. Young children's spatial working memory (SWM) responses are biased toward the center of a homogenous space, whereas older children and adults subdivide the space along the midline symmetry axis, and their memory responses are biased away from the center of the space. According to Dynamic Field Theory (DFT), a dynamic systems model of spatial cognition, developmental changes in geometric biases in SWM are caused by changes in neural interaction in SWM and the development of children's perceptual abilities. Specifically, over development children's ability to perceive the location of axes of symmetry improves quantitatively. Ortmann and Schutte (2010) examined whether there were changes in children's ability to perceive the location of symmetry axes by having 3- to 6-year-olds and adults determine on which half of a large monitor a smiley face was located. Three- to 6-year-olds were above chance at classifying all but the location closest to midline, and over development there was improvement in the ability to localize the axis. Despite this apparent ability to perceive the symmetry axes, 3-year-olds do not reliably subdivide space in SWM tasks (Huttenlocher et al., 1994; Schutte et al., 2009). Perhaps their perception of midline is too "fuzzy" for them to use it as a reference axis in memory. We conducted a pilot study with 3-year-olds to examine whether perception of the midline symmetry axis was related to memory biases. The DFT predicts that biases toward midline will be reduced for children who are better able to localize midline, and this relationship will depend on the location of the target in memory. That is, for 3-year-olds, errors to targets that are close to midline will not be correlated with the perception of midline, because these targets are strongly biased toward midline. Memory errors to targets farther from midline, however, should be correlated with their perception of midline. The prediction was supported. Children who were better able to determine on which side of midline a target was located were more likely to be biased away from midline in the spatial memory task for all targets except the two closest to midline. These results support the DFT and demonstrate interactions between perception and cognition over development.

Spatial Language

Three-year-olds produce the spatial terms *in, on,* and *under*, whereas 4-year-old children produce more complex terms such as *back* and *front*. Very little is known about

children's production of the complex terms *between* and *middle*. These terms require comparison with two reference objects, which involves considerable conceptual and syntactic complexity. What mechanisms might facilitate young children's mastery of such complexity? One potential mechanism is scaffolding—the process by which experts provide support to help children accomplish more than they could do on their own (Vygotsky, 1978). The goal of this study was to specify the impact of four prompt types (scaffolding) in facilitating 4- and 5-year-old children's use of *between* and *middle* in a direction-giving task in relation to overhearing conversations. These prompt types were identified via an observational study involving parents and children. On each trial, 4- and 5-year-old children hid a mouse in a small object *between* two identical furniture items and then told a doll where the mouse was hiding. Children were randomly assigned to one of six conditions: between directive prompting (Is the mouse in the basket *between* the couches or in the basket *by* the couch?), middle directive prompting (Is the mouse in the basket in the *middle* of the couches or in the basket *by* the couch?), non-directive prompting (Can you tell the doll anything more?), control (no prompting), overhearing between (overhearing conversations describing the dollhouse set up using *between*), and overhearing middle (overhearing conversations using *middle*). Children who received directive prompting involving *between* or *middle* were highly likely to incorporate these terms into their directions. In contrast, children who received non-directive or no prompting and children who overheard conversations containing *between* or *middle* evinced very limited use of these terms. Together, these findings indicate that children's incorporation of *between* or *middle* was not due primarily to priming effects but was facilitated by the directive nature of scaffolding provided.

Words, Maps, and Spatial Relations

Spatial relations like *in, across,* or *within* are fundamental to spatial thinking, but some spatial relations are more challenging than others. The present work investigates children's understanding of the complex relation *midpoint* (or *middle*). *Midpoint* is complex in that it encodes location relative to more than one entity, and it integrates both qualitative and quantitative spatial information. Here, we explore two kinds of symbols that might help children understand this relation: *labels* and *maps*. Previous studies have shown that relational language can help children reason about spatial relations (Loewenstein & Gentner, 2005), and in fact, children's knowledge of the terms *middle* and *between* predicts their performance on a challenging *midpoint* search task (Simms & Gentner, 2008). Maps also promote relational representations of space (Uttal, Fisher, & Taylor, 2006), but 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 explored the relative effectiveness of labels and maps, separately and in combination, as tools to communicate spatial relational information to preschoolers. Two- and three-year-olds played a challenging hiding-and-finding game: a hidden object was always located at the midpoint between two landmarks, but the positions of the landmarks changed on each trial. Consistent with prior findings, hearing a label during the task improved children's accuracy. Surprisingly, however, children's performance did not benefit from seeing a map. These results invite further exploration into the conditions under which maps are helpful to young children, and reinforce the role of language as a powerful tool for conveying spatial relational information.

Spatial Symbols: Maps, Words, and Gestures

Learning to use spatial symbols plays an important role in the development of spatial cognition. For example, learning to understand the meaning of left and right may influence children's mental representation of spatial information (Shusterman & Spelke, 2005). Likewise, coming to see and to think about the world from the perspective of maps can contribute to the development of spatial cognition (Davies & Uttal, 2007). Symbols differ in terms of what kinds of spatial information they communicate efficiently or effectively. For example, in language, spatial relations must be communicated serially. In contrast, maps can depict multiple relations among locations. Gesture can be construed as intermediate; we often can imply multiple locations with our hands, such as by laying out a spatial framework and pointing out locations relative to that framework. We investigated both the development of children's ability to communicate spatial relations and the influences of this communication on spatial thinking. Children (ages 6 and 8) learned the layout of six different toy animals within a room by walking through the space along a single, specified route and anticipating what could be found in each of the six hiding locations. Children were then asked to communicate the locations to their parents in one of three forms: language alone, language augmented by gesture, or map drawing. Children returned to the original room after they had communicated the locations and were asked to make judgments about spatial relations that they had not experienced. In the language condition, 6-year-olds and 8-year-olds tended to name only the animals that they had experienced. Asking children to add gesture improved communication, but not reasoning. Asking children to draw a map improved both communication and reasoning. These results suggest that the act of communicating spatial information influences children's thinking about spatial information.