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Getting the big picture: Development of spatial scaling abilities

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ABSTRACT

Spatial scaling is an integral aspect of many spatial tasks that involve symbol-to-referent correspondences (e.g., map reading, drawing). In this study, we asked 3–6-year-olds and adults to locate objects in a two-dimensional spatial layout using information from a second spatial representation (map). We examined how scaling factor and reference features, such as the shape of the layout or the presence of landmarks, affect performance. Results showed that spatial scaling on this simple task undergoes considerable development, especially between 3 and 5 years of age. Furthermore, the youngest children showed large individual variability and profited from landmark information. Accuracy differed between scaled and un-scaled items, but not between items using different scaling factors (1:2 vs. 1:4), suggesting that participants encoded relative rather than absolute distances.

The ability to reason about objects in space and to represent spatial layouts is an important aspect of everyday cognition, with evolutionary and adaptive importance. Any mobile being must represent its position with respect to the spatial environment to be able to navigate in its world. In addition, the human species has a unique ability to devise tools and technologies to help meet these cognitive challenges. For example, maps and global positioning systems (GPSs) help to represent spatial relations and configurations. Such navigational tools usually depict small-scale two-dimensional representations of parts of the referent space. In order to understand and interpret these spatial representations, we must understand that they are miniaturized (and often arbitrary and symbolic) versions of their large-scale counterparts. In addition, we must be able to scale the spatial information provided by the

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representations in order to apply it to the referent space. *Spatial scaling*, or the ability to transform distance information from one representation to another one of a different size thus constitutes an integral component of map reading, navigation and other spatial tasks that involve representational systems. Moreover, spatial scaling may be a spatial ability important for success in science, technology, engineering and mathematics. Wai, Lubinski, and Benbow's (2009) analysis of a large longitudinal data set focused on mental rotation and other abilities assessed in traditional paper-and-pencil tests, but we must also consider the scaling demands of the sciences. For example, an engineer may interpret a blueprint of a large building, a geoscientist may use a sketch to visualize the processes that led to the formation of the earth, an astronomer may study a Hubble Ultra Deep Field Image of the universe, and a science text may map the structure of a solar system onto a model of an atom.

In developmental research, spatial scaling has often been investigated in the context of map-reading skills (e.g., Liben & Downs, 1994; Uttal, 1996, 2000). However, interpreting maps requires a number of additional spatial competencies (Liben & Downs, 1994). In order to comprehend maps and to be able to use them effectively, one must understand (a) the correspondence of the symbols on the map to their referents, (b) the orientation of the map and how to align it with the referent space if necessary, (c) the viewing angle of the map – for example whether it represents a space from an overhead view, (d) how a three-dimensional space is projected onto a two-dimensional one and (e) the viewing distance, that is, the scale of the map, and how to relate distances on the map to those in the referent space. The present study focuses on the last competency – the ability to scale distances, aiming to assess its development distinct from the other four competencies.

Research on symbol-referent correspondence has shown that children as young as 3 years have a basic understanding of symbolic relations between maps or scale models and large-scale referent spaces (DeLoache, 1987, 1989, 1991). Similarly, young 3-year-olds are able to locate a target object in a larger room after seeing the corresponding location in a model (Blades & Cooke, 1994). However, this ability appears to be restricted to unique hiding places. When the hiding place was one of two identical places (e.g., under one of two identical-looking chairs), such that spatial relations had to be taken into account, it was not until 4 years of age that children succeeded. When a hiding place is unique, children may solve the task by associating a symbol with the hidden object and establish symbolic or 'representational' correspondence (Liben & Yekel, 1996). However, spatial or 'geometric' correspondence (Downs, 1985) is necessary to link spatial properties of the referent space with spatial features of a map or model.

According to Liben and Downs (1994), extracting spatial information and understanding geometric properties of a map rely on a basic understanding of projective spatial concepts, as described by Piaget and Inhelder (1948/1956). In their seminal work on *The Child's Conception of Space*, Piaget and Inhelder distinguished between *topological, projective and Euclidean* space. They proposed that *topological* space was "psychologically primitive" and referred to intrinsic properties internal to the figure/object. Between approximately 4 and 7 years of age, basic spatial concepts such as proximity, separation, order, enclosure, and continuity characterize children's spatial representations, so that, for example, a drawing of a human face will place the eyes close to each other and inside the boundary of the head. An understanding of topological space may be sufficient for establishing symbolic correspondences and for solving map tasks with unique hiding places, if the object's location can be determined by means of remembering enclosure, or proximity to a specific landmark. An understanding of *metric* and *projective* space, however, is necessary for locating objects relative to one another and in accordance with general perspective or projective systems. According to Piaget and Inhelder, it is not until after 7–8 years of age that children's spatial representations begin to reflect distances and proportions, or that they recognize two rectangles of different sizes but equal proportions as having the same shape.

In line with these theoretical accounts, research has shown that extracting spatial information from representations is difficult for young children (Liben & Downs, 1993; Uttal, 2000). Using a task that required placing stickers on a map to indicate the location of objects in their classrooms, Liben and Yekel (1996) found that 4–5-year-olds had considerable difficulties understanding geometric and even representational correspondences. They had troubles interpreting maps even when the task involved a highly familiar room, the map was presented simultaneously and in alignment with the referent space, and the task required the identification of only a single location at a time.