The Long and Short of It: Development of Spatial Scaling Abilities

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Spatial scaling – the ability to transform distance information from one space to another space of different size – constitutes an integral aspect of many spatial tasks that involve different representational systems or symbol-to-referent correspondences (e.g., map reading, navigation, drawing, etc.). It potentially also bears relevance to physical, geometrical or mathematical reasoning, which involves proportional thinking, referencing, and comparing of magnitudes. Spatial scaling ability may thus constitute an essential prerequisite for success in science, technology, engineering and mathematics (STEM) disciplines.

Spatial scaling has gained interest in developmental research because of its relevance to the development of map-reading skills (Liben & Downs, 1989, 1994; Uttal, 1996, 2000). Studies on spatial mapping have often shown poor performance in preschoolers, and children's difficulties in interpreting maps have been associated with a lack of understanding of scale relations as well as difficulties with extracting spatial information from maps (Liben & Downs, 1989; Uttal, 1994, 1996, 2000; Liben & Yekel, 1996; Blades & Cooke, 1994; Liben, Moore, & Golbeck, 1982).

However, other findings suggest that the ability to scale distances can be observed earlier if simpler tasks are employed. Huttenlocher, Newcombe, and Vasilyeva (1999) showed that all of the 4-year-olds and about half of the 3-year-olds tested were successful at translating distances from a map to a larger space if they only had to figure out the location of one object along one single dimension. Vasilyeva and Huttenlocher (2004) found that approximately 60% of the 4-year-olds and 90% of the 5-year-olds tested succeeded in locating an object along two dimensions. Thus, empirical evidence exists that spatial scaling abilities develop considerably during the preschool years.

In the present study, we investigated the ability to scale distances, with the objective of developing an assessment tool to investigate the emergence of this integral aspect of spatial thinking within a wide age range. We developed a task based on the above-mentioned research by Huttenlocher and colleagues, in which children had to use information provided by a small map or model to find an object that was hidden in a larger space. We created a two-dimensional version of this task, in which we asked 3- to 6-year-old children as well as adults to locate hidden objects in a two-dimensional spatial layout (hiding space) using information from a second spatial representation (map). By presenting different hiding spaces and different maps, we examined which factors (scaling factor, landmarks, boundary information) affect the emergence and early understanding of spatial scaling.

We tested 80 children at 3, 4, 5 and 6 years as well as 12 adults. Half of the participants in each age group were female. Participants were told a short story about Farmer Fred, who had a big farm with many chickens and different fields. The chickens hid their eggs in the fields every morning when Farmer Fred wanted to collect them, and participants were asked to help Farmer Fred find the eggs. Next, the participants saw a color drawing of a field and were told that the first chicken hid her egg somewhere in this field. A map was placed directly to the right of the field and participants were told that this picture showed where the chicken hid her egg, and that the egg would be in the same place in the field. Children were then asked to put a small rubber peg on the field where they thought the egg was hidden. Participants' responses were measured as x and y-coordinates, and the absolute distances from the responses to the target locations were calculated. The experiment consisted of 25 trials and lasted approximately 10 minutes.

The hiding spaces and corresponding maps varied in shape of their boundaries (narrow strips, rectangular fields, or circular fields with landmarks, see Figure 1). The presented maps also varied in scaling factor (1:1, 1:2, 1:4). Some trials that did not require scaling were included to provide information on how well children can use information from one representational space and apply it to another, regardless of their scaling abilities.

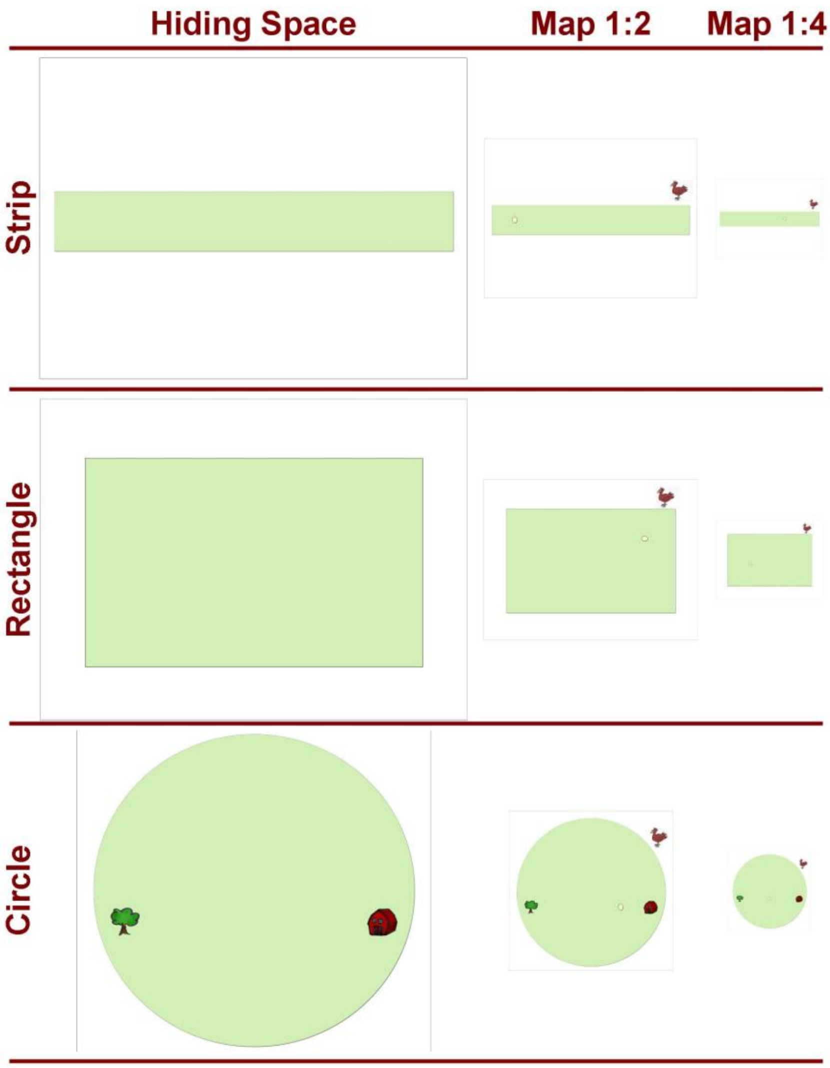

Figure 1. Examples of presented hiding spaces ("fields") and maps. Note that maps of scaling factor 1:1 that were of the same size as the corresponding hiding spaces are not shown here.

Results showed a clear developmental progression of spatial scaling abilities, with large progress between 3 and 4 years and between 4 and 5 years but with no notable difference between 5 and 6 years and between 6 years and adults (see Figure 2). Furthermore, individual differences decreased with age, with 3- and 4-year-olds showing particularly large variance.

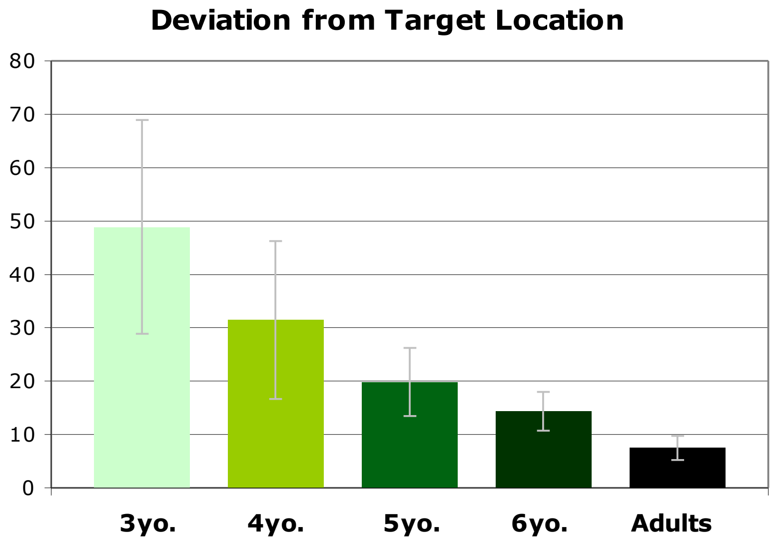

Figure 2. Mean deviations from target locations (and *SD*) per age group.

Participants performed better on trials that did not require scaling than on those that did require scaling, and this difference decreased with age. However, there was no significant difference between scaling factors 1:2 and 1:4. If children did not scale distances at all and merely reproduced the distance from - for example - the hidden object to a landmark, we would have expected larger errors for larger scaling factors. The fact that there was no significant difference in accuracy between scaling factors 1:2 and 1:4 suggests that children used a more intuitive or holistic strategy rather than an abstract or computational approach. The result that young children's accuracy was better but still far from perfect for the un-scaled trials shows that children's difficulties with scaling were partly but not entirely due to difficulties with using information from one representational space and applying it to another.

Furthermore, results showed that all but the 3-year-olds performed best on trials with circular boundaries and landmarks and worst on trials with rectangular boundaries, even though the areas were comparable in size. There was no difference in accuracy between boys and girls.

Our results suggest that spatial scaling abilities undergo considerable development between 3 and 5 years of age, that there are large individual differences, and that there is ample room for improvement at this age. The new assessment tool for spatial scaling abilities has proven to be well-suited for detecting developmental progress and individual differences in children of a large age range. As we learn more about the ways in which young children develop spatial transformation skills, and how this influences their ability on similar and more complex tasks that build upon those skills, we can gain a better understanding of how to identify children at risk of developing spatial delays at very young ages, and exactly what type of risk these delays pose in terms of later cognitive functioning. This kind of information can enable early intervention and results from this study may be used to develop age-appropriate training material to improve spatial scaling abilities at a young age.

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