Journal of Experimental Child Psychology 164 (2017) 152–162

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Developmental changes in the mental transformation of spatial arrays

Christos S. Michaelides *, Marios N. Avraamides

Department of Psychology, University of Cyprus, 1678 Nicosia, Cyprus

ARTICLE INFO

Article history:
Received 15 May 2017
Revised 20 July 2017
Available online 17 August 2017

Keywords:
Spatial memory
Spatial cognition
Spatial transformations
Mental rotation
Spatial development
Cognitive development

ABSTRACT

An experiment was conducted to investigate the spatial memory and transformation of spatial relations in a sample of 7-, 9-, and 11-year-olds and to compare their performance with that of adults. Four pictures of animals were presented at different locations on the outline of a circle. Participants were instructed to memorize the array of locations and then, in a direct retrieval task, to reconstruct it from memory on a piece of paper that included only the circle outline. Then, in the transformation task, participants were asked to randomly place one of the animals at a new position around the circle and then to place the remaining three animals so that object-to-object locations were preserved. Results from the direct retrieval task showed that 7-year-olds were less accurate than older children and adults, whereas 9- and 11-year-olds showed comparable performance to each other and to adults in reconstructing the array. Results from the transformation task revealed that adults were more accurate than children and that 11-year-olds were more accurate than 7-year-olds. There was no difference between 9- and 11-year-olds. Overall, these findings suggest that the ability to perform spatial transformations (a) develops gradually during childhood and (b) has a steeper developmental slope than the simple retrieval of memorized spatial information.

* Corresponding author.
E-mail address: chrmicha@gmail.com (C.S. Michaelides).

http://dx.doi.org/10.1016/j.jecp.2017.07.013
0022-0965/

Introduction

The ability to remember where things are in our environment is fundamental to our everyday functioning and is inherent to many tasks that form our daily routines. For example, we find our way to our kitchen every morning because we remember where it is relative to our bedroom. Similarly, we find our way to work because we know where it is located relative to our house and to other landmarks in our city. Tasks like these rely on our ability to form and maintain in memory stable representations containing spatial relations about locations in the environment, be it objects in our house or landmarks in our city.

Most of the spatial tasks of everyday life require further processing than what the simple retrieval of stored spatial relations entails. For example, ensuring that we are on the right course to work also requires knowing how we are oriented, at various positions in the route, relative to visible and non-visible landmarks of the environment. More complex tasks may also entail even more demanding processing. For example, navigating an unfamiliar environment based on a misaligned "You Are Here" map may require rotating the map in our head to match the orientation of the visible environment (see Montello, 2010). Such tasks, which require the transformation of spatial relations held in memory, are cognitively demanding and often lead to substantial decrements in performance (Hatzipanayioti, Galati, & Avraamides, 2016; Meneghetti, Muffato, Varotto, & De Beni, 2017). The goal of the current study was to examine how well children of different ages transform memorized spatial relations and to compare their performance with that of adults in order to characterize the developmental trajectory of this ability.

Much of previous developmental research on spatial transformations has focused on perspective taking, the ability to mentally observe an object or an array of objects from a viewpoint other than the one that is physically occupied. This research has shown that although young children and even infants understand that others may see an object that is not visible from their own viewpoint (e.g., Flavell, Everett, Croft, & Flavell, 1981; Masangkay et al., 1974), those under 5 years of age are typically unable to perform perspective-taking tasks with layouts containing multiple objects (e.g., Flavell, Flavell, Green, & Wilcox, 1980; Frick, Möhring, & Newcombe, 2014; Masangkay et al., 1974; Pillow & Flavell, 1986). As a result, Frick et al. (2014) proposed that the perspective-taking ability continues to develop through the early school-age years, but tasks involving perspective taking remain difficult and cognitively demanding even for adults.

Compared with perspective taking, mentally rotating an array of objects seems to be an even more difficult task (Amorim & Stucchi, 1997; Carpenter & Proffitt, 2001; Huttenlocher & Presson, 1979; Simons & Wang, 1998; Wraga, Creem, & Proffitt, 2000; but see Kozhevnikov, Motes, Rasch, & Blajenkova, 2006). In an early study, Huttenlocher and Presson (1979) asked 8- and 9-year-old children to study an array of four objects and then imagine either their selves moving to a new position around it or the array rotating while they remained still. Then, the children were asked to report which object would be at a specific egocentric direction (e.g., to their left/right). Results showed that children made more errors when they mentally rotated the array than when they imagined moving around it. Similarly, in a study with adults, Wraga et al. (2000) had participants view an array of four objects and carry out, after memorizing the configuration, either mental rotation or perspective taking. Specifically, they were asked to either imagine the array rotating or imagine themselves rotating around the array and to name objects at given positions (e.g., name the object on the right/left/top/bottom). Results showed that participants were slower and made more errors in the mental rotation task compared with the perspective-taking task.

In a more recent experiment, Nardini, Burgess, Breckenridge, and Atkinson (2006) asked 3- to 6-year-old children to recall the location of a hidden toy placed in an array of 12 identical containers bordered by specific landmarks (e.g., toy houses, animals). In one condition following learning, the experimenters rotated the whole array while children maintained their initial viewpoint. Results in this condition showed that performance at 3 or 4 years of age was significantly below chance, and only 5- and 6-year-olds could effectively retrieve the hidden toy. According to Nardini and colleagues, the above-chance performance of the 5- and 6-year-olds to retrieve the hidden toy was due to an