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Individual differences in the representations of novel environments

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Abstract

The present research investigated individual differences in representations of a novel environment. Thirty-eight participants traversed an unfamiliar route over two floors of a building and drew sketch-maps of the route. Participants also completed a mental rotation task and route knowledge tasks: orientation (pointing to nonvisible landmarks), landmark recognition, route tracing on a floor plan, and route retracing tasks. Based on spatial accuracy, participants' sketch-maps were classified as one-dimensional, two-dimensional, and three-dimensional, and the types of sketch-maps were associated with participants' spatial ability and their performance on route knowledge tasks. Our findings showed that individual differences in visual–spatial abilities predicted the types of environmental representations that adults formed and thus provide evidence against stage/sequential models that attribute differences in environmental representations exclusively to differences in experience.

1. Introduction

Interest in cognitive representations of environments ranges from city planning (e.g. Lynch, 1960; Appleyard, 1969; Antes, McBride, & Collins, 1988) and geography (e.g. Montello, 2002) to spatial cognition and reasoning (e.g. Tolman, 1948; Thorndyke & Goldin, 1983; Tversky, 2003). Since Tolman (1948) found that more general spatial representations of an environment (i.e. beyond chained stimulus-response associations to a goal) guide spatial navigation, considerable research on cognitive representations of environments has focused on the development of such representations with maturation among children (see Piaget & Inhelder, 1967; Siegel & White, 1975) and with experience among children and adults (e.g. Devlin, 1976; Thorndyke & Hayes-Roth, 1982; Aginsky, Harris, Rensink, & Beusmans, 1997). Developmental researchers have suggested that children's abilities to represent environments follow a developmental sequence from concrete, isolated, egocentric representations to abstract, hierarchically integrated, allocentric representations (see Piaget & Inhelder, 1967; Siegel & White, 1975). Furthermore, researchers have suggested that adults' development of representations of environments follows an analogous but experience-based sequence (see Siegel & White, 1975). In the present study, however, we question whether adults' representations necessarily follow such an experience-based sequence, and we instead propose that individual differences in visual–spatial ability predict the types of representations that adults form.

Although there are variations in the definitions, sequential/stage models of the development of environmental representations typically draw distinctions between *landmark* representations (i.e. knowledge of visually distinct objects and scenes in the environment), *route/procedural* representations (i.e. sequentially organized knowledge of locations encountered along the route and actions performed at the locations) and *survey* representations (i.e. spatially organized knowledge of locations and routes) (e.g. Siegel & White, 1975; Thorndyke & Goldin, 1983). According to sequence/stage theorists, children's abilities to represent environments (see Piaget & Inhelder, 1967; Hart & Moore, 1973; Siegel & White, 1975; Moore, 1976) and adults' representations of environments (e.g. Appleyard, 1970; Siegel & White, 1975; Evans, Marrero, & Butler, 1981;

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Thorndyke & Hayes-Roth, 1982) progress in a specific sequence. Siegel and White, for example argued that (1) landmarks are first remembered, (2) actions are associated with landmarks, (3) landmark-action sequence pairings are organized to form routes, (4) an objective frame of reference is established, and (5) the routes are remembered within the objective frame of reference as survey representations. Children's representations then will depend on their specific stage of development, but adults' representations will depend on their experiences (e.g. number of times traversing the routes) in the environment.

To test sequential model predictions of adults' representations, Thorndyke and Hayes-Roth (1982) examined the survey knowledge of employees who had worked at a building 1–2 months, 6–12 months, or 12–24 months and of a group of participants who had no prior experience in the building but who were allowed to study the building floor plan. Survey knowledge of the building was assessed by having all of the participants judge straight-line distances between landmarks (a Euclidean distance estimation task), judge distances between landmarks along specific routes (a route distance estimation task), indicate directions to landmarks from various points in the building (an orientation task), and indicate the location of landmarks relative to two reference locations on an otherwise blank page (a landmark placement task). Thorndyke and Hayes-Roth found that greater experience within the building positively correlated with performance on Euclidean distance, landmark placement, and orientation tasks. Thorndyke and Hayes-Roth also found that survey knowledge could be acquired from studying floor plans (i.e. without direct navigation experience); however, participants who formed the survey representations from studying floor plans were less accurate on the route distance and orientation tasks than employees who had navigational experience within the building.

Although the above data seem to support sequential/stage models (Thorndyke & Hayes-Roth, 1982) and these models are considered a dominant framework for environmental representations (see Montello, 1998), several studies have revealed data that challenge the experience-based sequential/stage progression from landmark- to route- to survey-type representations of environments. Many studies have revealed rather wide individual differences in performance on navigation tasks (e.g. sketch-map, orientation, and backtracking tasks) following relatively little exposure to an environment (e.g. Devlin, 1976; Rovine & Weisman, 1989; Hirtle & Hudson, 1991; Lawton, Charleston, & Zieles, 1996; Aginsky et al., 1997). Devlin, for example found participants who could draw survey-type sketch-maps of a town after residing there for less than 3 weeks. Aginsky et al. examined the environmental representations of participants who demonstrated error-free performance in traversing a route learned in a virtual reality driving simulator, and like Devlin, Aginsky et al. found that after relatively little exposure to the route ($M = 8$ times through), some participants could draw survey-type sketch-maps of the route (whereas others drew landmark- or route-type sketch-maps). Furthermore, Moeser (1988) found that experience in a building did not lead to survey-type representations: Neither first nor third year student nurses drew survey-type sketch-maps of their clinical training building; 6 of 10 first year and 5 of 10 third year nurses drew landmark-type maps, and the others drew route-type maps. Finally, Rovine and Weisman found participants who could draw survey-type sketch-maps of a novel environment after a single traversal of a route through the environment. After walking a route through an unknown downtown area, participants drew sketch-maps of the area, and Rovine and Weisman classified the sketch-maps based on the inter-relations among the paths. They identified five types of sketch-maps: sequential, spatial-mosaic, spatial-linked, incomplete spatial-patterned, and complete spatial-patterned. The fact that complete spatial-patterned sketch-maps (i.e. survey-type sketch-maps) were drawn by participants after only one exposure to an environment challenges the necessity of experience in forming survey-type representations.

Although Devlin (1976), Aginsky et al. (1997), and Moeser (1988) have provided evidence that challenges sequential/stage models, issues regarding the control of experience prevent the unequivocal acceptance of their data as challenges to these models. Devlin and Moeser did not control participants' experience in the environments (e.g. which routes were traversed and how many times), and although Aginsky et al. (1997) had their participants traverse the same route, their data do not address whether all participants formed landmark-type representations after their first exposure to the route and then with additional exposure some participants went on to form survey-type representations. Finding survey-type representations following a *single* exposure to a route through a novel environment, as Rovine and Weisman (1989) found, provides the strongest evidence that survey-type representations do not necessarily follow from a landmark-to-route-to-survey progression. Rovine and Weisman's instruction to draw a map of the downtown area, not just the route traveled, however, may have led participants to spatially structure their drawings based on their knowledge of a typical city. Despite these problems, however, these studies provide some evidence that adults' environmental representations do not necessarily follow a landmark- to route- to survey-type progression.

In contrast to sequential/stage models, we hypothesize that individual differences in visual–spatial abilities (rather than experience alone) predict the types of environmental representations that adults form. In