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Extended experience benefits spatial mental model development with route but not survey descriptions

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Abstract

Spatial descriptions symbolically represent environmental information through language and are written in two primary perspectives: survey, analogous to viewing a map, and route, analogous to navigation. Readers of survey or route descriptions form abstracted perspective flexible representations of the described environment, or *spatial mental models*. The present two experiments investigated the maintenance of perspective in spatial mental models as a function of description perspective and experience (operationalized through repetition), and as reflected in self-paced reading times. Experiment 1 involved studying survey and route descriptions either once or three times, then completing map drawing and true/false statement verification. Results demonstrated that spatial mental models are readily formed with survey descriptions, but require relatively more experience with route descriptions; further, some limited evidence suggests perspective dependence in spatial mental models, even following extended experience. Experiment 2 measured self-paced reading during three successive description presentations. Average reading times over the three presentations reduced more for survey relative to route descriptions, and there was no evidence for perspective specificity in resulting spatial mental models. This supports Experiment 1 findings demonstrating the relatively time-consuming nature of acquiring spatial mental models from route, but not survey descriptions. Results are discussed with regard to developmental, discourse processing, and spatial mental model theory.

PsycINFO Classification: Learning; Memory

Keywords: Mental models; Spatial memory; Reading comprehension; Verbal learning; Reading speed

1. Introduction

Spatial descriptions convey geographical information through language, generally describing map-like configuration details or the best routes between landmarks. When asking a passer-by for directions you may receive information from a bird's-eye view, analogous to the perspective taken while viewing a map, or from a first-person view, analogous to the perspective taken during navigation. These perspectives, along with mixes of them, are the primary means of conveying environment information through language (Golledge, 1992; Siegel & White, 1975). The present experiments investigate the acquisition and maintenance of spatial perspectives in memory as a function of description perspective (route or survey) and repetition.

2. Spatial descriptions

Survey descriptions, like maps, convey spatial information in an aerial (allocentric) perspective, using an extrinsic reference frame (i.e., relative to other spatial information) and cardinal directions (*north*, *south*, *east*, and *west*). In contrast, route descriptions convey spatial information from a first-person (egocentric) perspective, using an intrinsic reference frame (i.e., relative to the viewer) that guides readers on an imaginary tour, conveying information about landmarks, distances, and turns (Levelt, 1982; Taylor & Tversky,

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1992a, 1992b). Considering these differences, one might expect correspondingly different mental representations following study. However, most work has demonstrated that with both route and survey descriptions individuals tend to develop abstracted and comprehensive *spatial mental models* of the described environments (Brunyé & Taylor, in press; Ferguson & Hegarty, 1994; McNamara, Hardy, & Hirtle, 1989; Noordzij & Postma, 2005; Taylor & Tversky, 1992a). These models are abstracted in that they do not appear to completely maintain described perspectives, and they are comprehensive in that they support map drawing and inferencing. This general finding extends earlier work suggesting multiple representations of memory for text (e.g., Bransford & Franks, 1971; Johnson-Laird, 1983; van Dijk & Kintsch, 1983) to the domain of spatial descriptions. Two primary indicators can be used as evidence for spatial mental models: first, the ability to go beyond the information provided in the text by generating inferences regarding novel spatial relationships, and second, the ability to make these inferences with a high degree of facility in both the learning perspective and the perspective not initially learned. The latter characteristic requires either perspective-free or perspective-flexible memory representations.

Conclusions regarding the degree of perspective flexibility of representations following alternative input formats have been mixed. Several studies have found source and memory perspective *dependence* in mental representations derived from maps and navigation (Evans & Pezdek, 1980; Leiser, Tzelgov, & Henik, 1987; Perrig & Kintsch, 1985; Sholl, 1987; Thorndyke & Hayes-Roth, 1982). Others have found results suggesting perspective *independence* or flexibility (Ferguson & Hegarty, 1994; McNamara et al., 1989; Taylor & Tversky, 1992a). Still other work suggests that spatial memory dependence upon source perspectives varies as a function of goals (Taylor, Naylor, & Chechile, 1999), experience (Golledge & Spector, 1978; Thorndyke & Hayes-Roth, 1982), test type (Shelton & McNamara, 2004), and instructions (Noordzij, Van der Lubbe, & Postma, 2005, 2006; Zwaan & van Oostendorp, 1993). Noordzij, Zuidhoek, and Postma (2006), for instance, report converging evidence that reader expectations have predictable influences on spatial mental model development; only when participants are told the nature of later tests do they show imagery and spatial mental model development during learning (assessed via EEG), and at test.

Taylor and Tversky (1992a) found that after reading survey or route descriptions participants could accurately draw maps of, and verify inference questions about the studied space. In fact, description study served these tasks as well as map study. In contrast, recent work using the same descriptions has demonstrated that participants appear to develop mental representations that are bound to the initial input perspective (Shelton & McNamara, 2004). When participants were tasked with scene recognition from various orientations there was a clear bias towards the first experienced path segment orientation of a route description, or the north-is-up characteristic of a survey description. This finding was replicated using video walkthroughs of the environments.

Clearly recent results are divergent with regard to the perspective-dependence and independence of spatial mental models. Much of this variation in findings, however, may in part be attributable to representational formats (e.g., Shelton & McNamara, 2004), study instructions (e.g., Noordzij et al., 2005, Noordzij, Van der Lubbe, & Postma, 2006), test types (e.g., Noordzij & Postma, 2005; Taylor & Tversky, 1992a), and individual differences (e.g., Denis, in press). An additional factor that may be particularly important towards the development of perspective-independent spatial mental models is experience or extent of learning (i.e., Bosco, Sardone, Scalisi, & Longoni, 1996). Indeed the possibility remains that people only develop spatial mental models when given sufficient experience with an environment; Taylor and Tversky (1992a) allowed up to three readings of a description per environment. The present work examines this specific issue by manipulating the amount of description exposure (through repetition) on spatial mental model development.

3. Experience and spatial representation

A number of studies have found that increased environment experience leads to more detailed and accurate spatial mental models (Appleyard, 1970; Golledge & Spector, 1978; Kuipers, Tecuci, & Stankeiwicz, 2001; Ladd, 1970; Lee & Tversky, 2005; Sholl, 1987; Thorndyke & Hayes-Roth, 1982. Tolman (1948) was perhaps the first to demonstrate that, through sufficient experience, animals can form what he termed *cognitive maps*, holistic mental representations of environments that can be recruited to solve novel spatial tasks. Appleyard (1970) & Ladd (1970) later suggested that these mental models could only be formed after extensive experience with landmarks and the routes between them. Golledge & Spector (1978) supported this notion by demonstrating that individuals' mental representations of heavily traveled environments were more integrated and configural than those for less-traveled areas. Furthermore, Thorndyke & Hayes-Roth (1982) demonstrated that increased navigation experience eventuates in configural knowledge formation, without exposure to physical maps. This finding is supported by later work (Sholl, 1987) demonstrating the availability of mental representations without a preferred perspective with extensive environmental experience. Finally, computational modeling of wayfinding in complex environments also predicts a positive relationship between the number of times an individual follows a path, and the development of a boundary-rich allocentric mental representation (Kuipers et al., 2001). Taken together, this work supports Siegel & White's (1975) theory of spatial knowledge development, which posits a progression from representing landmarks, the routes between them, and at the highest level integration into a spatial mental model. It is important to note that while much of this work assumes sequential mental model development it remains in question