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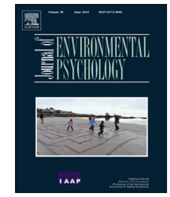

Pointing accuracy: Does individual pointing accuracy differ for indoor vs. outdoor locations?

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A B S T R A C T

Pointing accuracy to and from indoor and outdoor locations was examined to reveal any significant differences in the accuracy with which we recall the arrangement of unseen locations in the world around us. Spatial ability and navigational strategy were included to better understand the cognitive processes involved in pointing accuracy and subsequent environmental knowledge. Results from this study indicate that knowledge for indoor and outdoor environments is indeed different. Individual pointing is more accurate to landmarks and locations that are inside buildings than to those outside, whether or not they point from an indoor or outdoor origin. As well, the preference for configurational and somewhat more complex navigational strategies, as expressed through questionnaire results, is positively correlated with increased pointing accuracy.

1. Introduction

We have all experienced navigational difficulties requiring maps, GPS, or other individuals at one time or another. Often these difficulties tend to arise in specific environments that vary for individuals. Some may be uncomfortable driving in a new city, while others may find it difficult to navigate in a complex building with many functions and floor levels. What is it about these differing environments that affect our ability to navigate efficiently? Studies have shown that despite becoming familiar with certain environments (such as the workplace), the navigational difficulties an individual first experiences can continue for years (Wang & Brockmole, 2003a). These difficulties may cause decreased safety, stress, discomfort, and loss of time. In extreme cases, getting lost in isolated environments can be life-threatening (Montello & Sas, 2006). Despite scientific evidence that the nature of an environment can impact how we learn and move through it, the majority of research relies on a common and relatively narrow set of principles of spatial knowledge acquisition and use. To remedy these issues, it is important to understand how navigation is affected by elements within and associated with the built environment.

There are a variety of characteristics within our environment, both visual and structural, that support navigation. Effective navigation is defined by Montello and Sas (2006) as requiring individuals to apply psychological skills such as perception and cognition in conjunction with motor behaviors. Goal directed use of knowledge, cognitive processes, and locomotion to travel from one location to the next is referred to as wayfinding (Montello & Sas, 2006). An important factor in wayfinding is orientation. For wayfinding to be effective, one must be aware of their position in relation to other places, destinations, and objects. Precision is often not required in orientation, as effective navigation can occur even when one's orientation is coarse or partial (Montello & Sas, 2006).

The availability of information during wayfinding differs among environments. Factors affecting these differences include differentiation (ability to distinguish between within environment elements), visual access, and layout complexity (Montello, 2007). Differentiation is characterized by variation in size, shape, and color of items; in the case of built environments; differences in architectural style tend to aid navigation. While increased within environment differentiation typically aids navigation, too much can be disorienting (Montello & Sas, 2006). Both differentiation and visual access affect landmark effectiveness during navigation. As well, the type and availability of landmarks is thought to affect navigational success (Goldberg, 2008). Outdoor landmarks tend to consist of large, highly visible objects such as buildings, while indoor landmarks tend to be smaller objects, such as lobbies, paintings, and other features (Giudice, Walton, & Worboys, 2010). Layout complexity is the final environmental factor that is thought to affect wayfinding. This factor is difficult to define, as complexity is dependent on individual abilities to visually and cognitively organize complex environments. If patterns and effective organization are apparent to the navigating individual, complex environments become much easier to understand and navigate (Montello & Sas, 2006).

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Differences between environments that might affect wayfinding or spatial knowledge acquisition have not been studied extensively within the spatial cognitive domain. Specifically, studies have yet to analyze any differences in our ability to locate and use indoor versus outdoor locations. As indoor spaces are considered more challenging for apprehension and learning, it would be useful to empirically test this logic (Goldberg, Wilson, Knoblock, Ritz, & Cockburn, 2008). One apparent difference between indoor and outdoor environments is the availability of landmarks. As noted above, landmarks utilized for indoor navigation tend to differ greatly in both availability and type from landmarks associated with outdoor locations. As well, the field of view available to an individual in each environment differs greatly with respect to the number of landmarks for building the cognitive maps for the entire surroundings. The distinction between indoor and outdoor environment belies the variation that can be found within either category. Perhaps the most compelling characteristic of indoor spaces is the constrained field of view created within built structures. Furthermore, limited visual access to the larger surrounding environment (either outdoor or indoors) could be potentially troublesome (Goldberg et al., 2008). This might suggest that outdoor landmarks are advantageous for navigation due to their visibility from several locations and greater distances, thus providing a reference for a variety of routes (Giudice et al., 2010). However, the constrained nature of indoor spaces and the visual framing that can support landmark storage and recall, could provide additional information for recording landmark location, as long as connection to the larger surrounding environment is available or possible. Landmarks are particularly important for orientation tasks as they are the basis of route knowledge and more complex survey knowledge (Belingard & Peruch, 2000). If individuals must rely on a high number of local landmarks indoors, presumably it would be difficult to build a survey map requiring greater use of route knowledge on the navigator's part.

1.1. Theoretical framework

To understand the differences in navigation and wayfinding ability, researchers have turned to the theoretical framework of spatial cognitive microgenesis, which is introduced by Siegel and White (1975), comprised of landmarks, route, and subsequent survey knowledge (Griffin, MacEachren, Hardisty, Steiner, & Li, 2006). According to spatial cognitive microgenesis, knowledge progresses from landmark knowledge to route knowledge, and ends in survey knowledge. Survey knowledge is a mental representation of space including both distance and directional relationships among landmarks (Griffin et al., 2006; Ishikawa & Montello, 2006; Montello & Pick, 1993). Route knowledge refers to the connections between landmarks and the knowledge required to get from one landmark to the next. Distance and direction are not necessarily encompassed in this form of knowledge (Ishikawa & Montello, 2006; Montello & Pick, 1993). Survey knowledge builds on landmark and route information and has been shown to create a cognitive representation of space that supports shortcutting and accurate pointing to distant unseen landmarks. This is generally assumed to be possible because the representations include both metric and non-metric elements. Unlike route knowledge, survey knowledge is thought to be metric, with distance and direction being accounted for, even on routes which have not been previously traveled (Ishikawa & Montello, 2006). Survey knowledge is responsible for our ability to take shortcuts, plan efficient routes, and point accurately to landmarks in the environment (Ishikawa & Montello, 2006; Montello & Pick, 1993). In essence, survey knowledge is a compilation of all previously learned routes and the intervening spaces which are subsequently combined and integrated into a series of mentally accessible routes (Ishikawa & Montello, 2006; Montello & Pick, 1993). To date, spatial cognitive microgenesis has been studied primarily in two-dimensional spaces. Only a few studies have utilized the large-scale three-dimensional spaces in researching orientation and wayfinding that will be used in the present study (Montello & Pick, 1993).

1.2. Cognitive mapping

Landmark, route, and survey knowledge are acquired via the process of cognitive mapping (Ishikawa & Montello, 2006). Cognitive maps refer to a global representation of space which we create through experience, learning, and problem solving (Goldberg et al., 2008). Spatial information and relationships are stored, recalled, and decoded via cognitive mapping (Montello & Sas, 2006). This phenomenon is an essential tool utilized in our daily life to solve both simple and complex spatial tasks, with new information being constantly acquired and integrated into the knowledge already held within our cognitive map (Ishikawa & Montello, 2006; Montello, 1998). Cognitive mapping is a component of spatial cognition which refers more generally to our internal structuring of space. It is not thought to rely on any one sensory modality more than others, and thus draws upon all of them (Golledge & Stimson, 1997). Experience and meaning must also be taken into account when discussing the development of cognitive maps. Each play an integral role in how information about an environment is acquired, stored, and recalled (Bell, 2002). As well, the way in which spatial information is encoded and subsequently represented and stored in our cognitive map does not appear to depend on the size of a space. Both large and small-scale spaces have been studied by Roskos-Ewoldsen, McNamara, Shelton, and Carr (1998) providing evidence that both spaces are coded using the same methods (Bell, 2002). Increasing our knowledge of how individuals process and understand spatial knowledge enables us to further predict and explain human behavior as well as ensure that planning and policy-making reflects the needs of the population (Montello, 2009).

1.3. Indoor vs. outdoor

It has been found to be more difficult to build cognitive maps for indoor versus outdoor locations. When discussing cognitive maps, outdoor spaces are typically referred to and thought of in either two, or two and a half dimensions (position and elevation). On the other hand, indoor locations have multiple floors and require cognitive maps to be thought of in three dimensions (Goldberg et al., 2008). In support of the concept that developing cognitive maps for indoor locations is more difficult, a number of studies have suggested that the complexity of a floor plan is the primary influence on wayfinding performance and is thus a main reason for the increased difficulty of navigating indoors. Moeser (1988) found that 56% of the variance in individual ability in wayfinding was explained by floor plan complexity, whereas experience with the floor plan of a building only accounted for 9%. According to Golledge and Stimson (1997), floor plans cannot be mentally represented until the building has been travelled repeatedly. Further, studies have provided evidence that individual spatial learning for the orientation of different sections of a building or interior rooms relative to outdoor environments is especially difficult. This holds true even after an individual has had continuous experience navigating the environment for several years (Wang & Brockmole, 2003a).

1.4. Potential contributions

There are several contributions that could be made by better understanding how spatial knowledge varies regarding indoor spaces, outdoor spaces, and their confluence. Floor plan