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Individual visuo-spatial factors and familiar environment knowledge: A structural equation modeling analysis

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ABSTRACT

Individual differences in visuo-spatial factors play an important part in environment learning when it comes to mentally representing environments, but little is known about how visuo-spatial factors (in terms of abilities and self-assessments) are related to an individual's representations of familiar environments. A group of 273 female undergraduates familiar with a university campus completed object-based visuo-spatial tasks (i.e., mental rotation and visuo-spatial working memory [VSWM] tasks), and questionnaires on their self-assessed wayfinding inclinations (i.e., sense of direction, visuo-spatial preferences, pleasure in exploring environments), and their spatial anxiety. Their spatial orientation performance was assessed with landmark locating and pointing tasks. The results of structural equation modeling showed that object-based visuo-spatial abilities and self-assessed wayfinding inclinations were related with spatial orientation performance. In particular, it was postulated that object-based visuo-spatial abilities (where rotation had an indirect effect through VSWM) and self-assessed wayfinding inclinations support spatial orientation performance. Spatial anxiety was only related to self-assessed wayfinding inclinations. Overall, these results show that a set of different individual visuo-spatial factors have a role in the representation of a familiar environment.

1. Introduction

A crucial goal in spatial cognition research is to identify which aspects are involved in supporting environment representations (also called cognitive maps; Tolman, 1948). One aspect crucial to the quality of a mental representation is the degree of familiarity with a given environment, gained through experience. Familiarity per se enables the construction of an elaborate and detailed mental map (e.g., Iachini, Ruotolo, & Ruggiero, 2009), which develops from an egocentric view (using one's own position as a reference to store spatial information) into an allocentric (or configurational) view, where landmarks, their positions, and the distances between them can be depicted irrespective of a person's position (Siegel & White, 1975). Not all individuals familiar with an environment develop representations with configurational features, however (Ishikawa & Montello, 2006), and - even when they are familiar with a certain environment - their performance varies (e.g., Ishikawa & Montello, 2006; Marchette, Yerramsetti, Burns, & Shelton, 2011). One possibility that has yet to be explored is that individual differences in visuo-spatial factors may intervene in supporting elaborate representations even when the environment is familiar.

Individual visuo-spatial factors comprise a set of object-based visuo-spatial abilities, including mental rotation (as measured by the Mental Rotations Test [MRT; Vandenberg & Kuse, 1978]), for instance. Another visuo-spatial ability is the visuo-spatial working memory (VSWM), which processes and retains visuo-spatial information. There is strong evidence of the role of both mental rotation (Weisberg, Schinazi, Newcombe, Shipley, & Epstein, 2014), and VSWM (Labate, Pazzaglia, & Hegarty, 2014) in representations of newly-learned environments.

Other relevant factors relate to how individuals assess their own inclination to approach and move in the environment, such as self-assessed Sense of Direction (SoD), i.e., the ability to locate and orient themselves in an environment (Kozlowski & Bryant, 1977). SoD has been found to be related to newly-acquired environment knowledge (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002), and it has been recently been shown to relate to personality traits too (Condon et al., 2015).

Studies on newly-acquired environmental information have often produced evidence of several individual visuo-spatial factors (both object-based and self-assessed) representing small-scale competences being related to spatial learning performance, which represents a large-scale competence (Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006; Wolbers & Hegarty, 2010). Such studies postulated that individual visuo-spatial factors can be conceived as predictors of environment information learning (Hegarty et al., 2006; Weisberg et al., 2014). The contribution of visuo-spatial individual factors (both

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object-based and self-assessed) to performance in tasks referring to a familiar environment has been less well explored, however.

To our knowledge, only De Goede and Postma (2015) approached the role of object-based visuo-spatial abilities in relation to tasks involving familiar environments. They found that participants highly familiar with their own city of residence performed better in tasks assessing environment representation than participants who were less so, but it was only in the former that performance was related to their object-based visuo-spatial abilities (i.e., mental rotation and VSWM). Familiarity and object-based visuo-spatial abilities thus seem to contribute jointly to an individual's mental representation of a well-known environment.

As for self-assessed wayfinding inclinations, some evidence has emerged of SoD being related to a higher spatial orientation performance in familiar environments (Burte & Hegarty, 2012; Hegarty et al., 2002; Prestopnik & Roskos-Ewoldsen, 2000).

It should be noted that there are several other self-assessments of an individual's inclinations to approach and move in an environment as well as SoD, including visuo-spatial preferences (Lawton, 1994; Pazzaglia & De Beni, 2001). Individuals may generally prefer to consider the spatial relations in a given environment using a survey mode, which is also called an orientation strategy (Lawton, 1994), or allocentric strategy (e.g., Münzer, Fehringer, & Kühl, 2016), in which case information is organized on the basis of landmarks and their relative positions. Or they may prefer a route mode, or egocentric strategy (Münzer et al., 2016), in which case information is organized sequentially like a route seen from one's own position. There is mixed evidence regarding whether visuo-spatial preferences and spatial performance in familiar environments are actually related (Nori & Piccardi, 2010; Prestopnik & Roskos-Ewoldsen, 2000).

Another personal visuo-spatial inclination concerns an individual's attitude to spatial exploration. Pappalardo et al. (2015) recently demonstrated that people moving in known environments can be divided into two categories: those who prefer to repeatedly move around the same known locations, and those who tend to move around numerous different places. People who take pleasure in exploring places tend to have a higher level of preference for the survey mode, higher level of SoD (De Beni, Meneghetti, Fiore, Gava, & Borella, 2014), and a good performance in spatial tasks in both known environments (Meneghetti, Borella, Pastore & De Beni, 2014) and new ones (Muffato, Meneghetti, & De Beni, 2016).

When considering individual characteristics, there is another construct – related more to personality – that can have a role in spatial performance; this is the spatial anxiety, which is defined as worrying about getting lost (Lawton, 1994). It reportedly has a negative role in spatial representations of new environments (Lawton & Kallai, 2002; Nori, Mercuri, Giusberti, Bensi, & Gambetti, 2009). It is also associated with low levels of self-reported SoD and pleasure in exploring places (De Beni et al., 2014), and a low preference for the survey mode (Lawton & Kallai, 2002).

Overall, research has shown that individual visuo-spatial factors have a role in supporting knowledge of familiar environments, with the main body of evidence showing the involvement of self-assessed wayfinding inclinations such as SoD (Burte & Hegarty, 2012), visuo-spatial preferences (Nori & Piccardi, 2010), and pleasure in exploring places (Meneghetti, Borella, Pastore and De Beni, 2014, Meneghetti, Ronconi, Pazzaglia and De Beni, 2014) in the way in familiar environments are represented. Little research has been done as yet (only one study to our knowledge, De Goede & Postma, 2015) to clarify the involvement of object-based visuo-spatial abilities in familiar environments. The contribution of spatial anxiety (Lawton, 1994) in relation to familiar environments should be examined more thoroughly too. There is also still a paucity of knowledge regarding the simultaneous role of these different individual visuo-spatial factors in relation to familiar environment representations.

Environment learning studies have showed that several individual visuo-spatial factors concur in affecting the accuracy of environment representations, and postulated that they act as predictors and mediators (Allen, Kirasic, Dobson, Long, & Beck, 1996; Hegarty et al., 2006). In a pioneering study, Allen et al. (1996) found that a spatial-sequential memory factor (measured with a task that involved showing moves charting a course within a 6×6 matrix) mediates the link between a visuo-spatial factor (measured by a set of tasks, including the MRT) and topographical knowledge of an environment (measured with several configurational tasks, such as map placement and distance estimations). In other words, the relationship between visuo-spatial abilities and topographical knowledge is not direct, but due to the intervention of spatial memory.

Their results suggested that variables mediating the relationship between visuo-spatial abilities and environment learning might be of a visuo-spatial nature and have storage functions, like VSWM. The role of VSWM as a variable intervening in the relationship between a-priori visuo-spatial ability (such as mental rotation) and new environment learning accuracy was confirmed by further studies (Meneghetti, Ronconi, Pazzaglia, & De Beni, 2014; Meneghetti et al., 2016). Although the same might plausibly apply to the representation of familiar environments too, no direct evidence of this has emerged to date.

The present study examined how individual differences in visuo-spatial factors (i.e., object-based visuo-spatial abilities and self-assessed wayfinding inclinations) related to the representation of a familiar environment. In particular, given the above-reviewed literature, we measured two cognitive abilities – mental rotation and VSWM (De Goede & Postma, 2015) – and self-assessed wayfinding inclinations – i.e. SoD, visuo-spatial preferences (Hegarty et al., 2002) and attitude to exploring places (De Beni et al., 2014). Spatial anxiety (Lawton, 1994) was also considered. Spatial orientation performance was assessed by means of a landmark locating task, which measures configurational features (Ishikawa & Montello, 2006) and a pointing task, which assesses flexibility in accessing information from different perspectives (Marchette et al., 2011).

In addition to individual visuo-spatial factors, gender is also a relevant source of variability in spatial tasks performance. It has been demonstrated that females perform less well than males in visuo-spatial tasks demanding both mental rotation ability (Hegarty & Waller, 2005; Parsons et al., 2004; Rilea, Roskos-Ewoldsen, & Boles, 2004; Voyer, Voyer, & Bryden, 1995), and VSWM (Coluccia & Louse, 2004). Females also have lower self-assessed ratings than males in SoD, preference for the survey mode (Pazzaglia & De Beni, 2001), and pleasure in exploring places (De Beni et al., 2014), and higher ratings for spatial anxiety (Lawton, 1994). Females may have a lower performance than males in environment representation tasks too, whether the environments are familiar (De Goede & Postma, 2015) or unfamiliar (Merrill, Yang, Roskos, & Steele, 2016; Piccardi et al., 2015). Given these gender-related differences, our analysis of individual visuo-spatial differences and environment knowledge focused on an all-female sample.

Using a structural equation modeling approach, we tested the structure of the relations between object-based visuo-spatial abilities, self-assessed wayfinding inclinations, spatial anxiety, and spatial orientation performance in a familiar environment. For object-based visuo-spatial abilities, mental rotation and VSWM were tested as separate variables (as in Meneghetti et al., 2016). The self-assessed wayfinding inclinations factor included SoD and pleasure in exploring places. Spatial anxiety was considered as a separate factor. The model was used to test whether these factors relate to spatial orientation performance in a familiar environment, based on the assumption that individual factors directly affect spatial orientation performance, in line with studies on new environment learning (Hegarty et al., 2006; Weisberg et al., 2014). The model was also used to identify possible indirect effects, as suggested by previous studies (Allen et al., 1996; Meneghetti et al., 2016).

2. Method

2.1. Participants

The study involved 273 female undergraduates (mean age = 20.21, $SD = 0.69$) at the beginning of their second year at the School of