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# The role of spatial abilities and self-assessments in cardinal point orientation across the lifespan

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ABSTRACT

The aim of this study was to investigate the relationship between age, spatial abilities, spatial self-assessments, working memory (WM) and environment knowledge, through an orientation task based on pointing in cardinal directions, across the adult lifespan using the structural equation modeling (SEM) approach. A group of 450 people from 20 to 91 years old was asked to point in the direction of cardinal points and to complete a set of spatial tasks, spatial questionnaires and WM measures. Results showed that, while spatial abilities and positive self-assessments mediated the influence of age on the ability to identify cardinal points, WM accounted for the age-related variance in spatial abilities and positive self-assessments. Age also had a direct influence on both positive and negative self-assessments. These findings indicate that both spatial cognitive abilities and spatial self-assessments have a crucial role in mediating the age effect on a measure of environment orientation.



Spatial knowledge acquisition is based on the construction of mental representations – or mental maps (Tolman, 1948) – defined as flexible internal representations of the structure of an environment (Wolbers & Hegarty, 2010). In the spatial cognition domain, it is widely accepted that spatial skills influence the adequacy of mental representations of an environment, which is typically tested in individuals given new environment information to learn (Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006; see the classification of spatial cognition activities in Montello & Raubal, 2012). Studies on young adults have shown that spatial abilities – in the sense of the capacity to generate, retain and transform abstract visual images (Lohman, 1979) – sustain the goodness of mental representations drawn from new environment learning (e.g. Allen, Kirasic, Dobson, Long, & Beck, 1996; Hegarty et al., 2006; Pazzaglia & Meneghetti, 2012). Spatial self-assessments, recorded by means of questionnaires on sense of direction and/or strategies used to orient oneself, have also been found to be positively related to spatial learning (e.g. Pazzaglia & De Beni, 2006). In a systematic study using the structural equation modeling (SEM) approach, Hegarty et al. (2006) demonstrated that both spatial abilities (measured with objective spatial tasks such as the Embedded Figures Test (EFT, Oltman, Raskin, & Witkin, 1971) and the Mental Rotations Test (MRT, Vandenberg & Kuse, 1978)) and spatial self-assessments of sense of direction (using the Santa Barbara Sense of Direction questionnaire, Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002) predicted the learning of a new environment from real or virtual exploration.

Processing resources such as working memory (WM) have also been shown to have a relevant role in environment learning and processing of spatial information (presented verbally as in Brunyé & Taylor, 2008, or visually – using maps – as in Coluccia, Bosco, & Brandimonte, 2007, or through navigation as in Labate, Pazzaglia, & Hegarty, 2014), either alone or jointly with spatial abilities and spatial self-assessments (e.g. Baldwin & Reagan, 2009; Meneghetti, De Beni, Gyselinck, & Pazzaglia, 2013).

Overall, research in the spatial domain on young adults has advanced our understanding of how spatial abilities, self-assessments and WM influence environment learning, but the combined effects of these variables have not been considered in young or older adults, nor across the adult lifespan. Surprisingly few studies have analyzed spatial resources and competences in relation to environment knowledge in older adults, or across the adult lifespan, despite their crucial influence on individuals' personal autonomy in everyday life.

The literature on aging has examined mental representations drawn from learning new environments using different types of input, testing them by means of different tasks. In general, these studies found older adults less efficient in learning a new environment and more impaired in terms of the properties of the mental representations they formed after receiving different inputs (navigation — Kirasic, 2000; Wilkniss,

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Jones, Korol, Gold, & Manning, 1997, or maps — e.g. Wilkniss et al., 1997, or descriptions of environments — Meneghetti, Borella, Grasso, & De Beni, 2011). The few studies on the role of spatial skills in older adults' acquisition of new environments indicated that, although spatial abilities decline with aging (Borella, Meneghetti, Ronconi, & De Beni, 2014; Salthouse, Babcock, Skovronek, Mitchell, & Palmon, 1990), they are related to spatial learning. For instance, the performance of young and older adults in spatial tasks like the MRT has been found to be positively related to environment learning from a map (Meneghetti, Fiore, Borella, & De Beni, 2011; Pazzaglia & De Beni, 2006) or through real navigation (Kirasic, 2000). Only the study by Kirasic (2000) systematically examined the relationship between age, spatial abilities (measured with objective spatial tasks) and environment representation (using navigational input), and the latter was operationalized in environment learning (testing the ability to infer spatial information by positioning landmarks on a map, or recognizing a scene, for instance) and way-finding behavior (i.e. finding a landmark in an environment learnt by navigation). Using the SEM approach, Kirasic found that: i) age-related differences in environment learning ability were mediated by the general spatial ability factor, but they also had a direct influence on environment learning; and ii) environment learning was the only direct determinant of way-finding behavior, while age and spatial abilities had only an indirect effect on this ability. These results indicate that the influence of age and spatial abilities on way-finding behavior is mediated by environment learning. This type of result suggests that other variables (such as spatial ability), as well as age (as typically emerges from group comparisons in aging studies, e.g. Wilkniss et al., 1997), intervene in explaining environment learning performance. A limitation of Kirasic's study lies, however, in that an extreme-groups design was used (young vs older adults), and no spatial self-assessments or processing resources (WM) were considered. Although they have been less thoroughly investigated in aging, spatial self-assessments have a role in supporting spatial activities in older adults too, being related to performance in tasks that involve pointing to places after map learning (Pazzaglia & De Beni, 2006), and in spatial tasks (such as EFT and MRT; Borella et al., 2014).

It is clear from the above-mentioned studies that analyses on environment representation have focused on new environment learning. It is recognized that another aspect of spatial cognition concerns people's ability to orient themselves in the environment, to locate their own position ("where you are") in relation to a given reference point (a landmark or cardinal point, for instance; Montello, 2013), when the environment is new (e.g. Ishikawa & Montello, 2006; Lawton & Morrin, 1999) or familiar, as in the case of a map of their home town (Montello, 2010). The ability to orient oneself in one's surroundings is particularly important for older people too (as suggested by Meneghetti, Borella, Fiore, & De Beni, 2013), as they move around the places where they live on a daily basis, they need to retain their orientation skills in order to find and reach destinations, new addresses, and so on. In the present study, we opted to assess environment knowledge in terms of the ability to orient oneself by pointing in cardinal directions of one's own place of residence. Although this is a very quickly-implemented and ecological task, no studies on older adults have examined this ability, while some evidence on young adults encouraged us to adopt this measure because of its relationship with spatial skills. The orientation ability tested using pointing tasks was related to spatial skills recorded with objective tasks like the MRT (Meneghetti, Pazzaglia, & De Beni, 2011) and to spatial self-assessments (Pazzaglia & De Beni, 2006). Hence our interest in examining the relationship between age and environment orientation, and assessing whether intervening variables such as spatial skills and self-assessments, and WM mediate this relationship, as suggested by studies examining new environment learning (Kirasic, 2000).

The main aim of the present study was to use a variety of indicators to analyze the relationship between age, spatial skills (gleaned from objective tasks and spatial self-assessments), WM and environment orientation (as measured by tasks involving pointing in cardinal directions) across the adult lifespan (from 20 to 91 years of age). Objective and self-assessment measures of spatial skills were recorded because of their relevance to environment orientation performance tasks, which has been clearly demonstrated in young adults (Allen et al., 1996; Hegarty et al., 2006), and suggested by some evidence in older adults too (Kirasic, 2000; Meneghetti, Fiore, et al., 2011). Tasks measuring WM were included as well because of its role in complex cognitive spatial skills (e.g. Borella et al., 2014; Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001). WM also appears to mediate the age-related differences in spatial abilities (Salthouse, Mitchell, Skovronek, & Babcock, 1989).

The SEM approach was used to examine the pattern of the relationships between age, WM, spatial abilities, spatial self-assessments and environment orientation (cardinal points). The SEM is a statistical approach allowing simultaneously testing different relationships between variables – in our case, between age (expressed on a continuum from 20 to 91 years old), WM, objectively ascertained spatial abilities, spatial self-assessments, and environment learning performance – by testing the relationships between variables organized in a certain order and controlling for their interrelation (e.g. Kline, 2005). For the first time, to our knowledge at least, we used SEM to examine the relationship between variables (WM, objective spatial abilities and spatial self-assessments) that are theoretically assumed in the spatial cognition domain to influence environment learning performance (operationalized in our case in terms of pointing in cardinal directions), but whose role has never been tested simultaneously in young and older adults, nor across the adult lifespan.

First we tested the structure of the measures of spatial abilities and spatial self-assessments (single vs separate constructs) to newly ascertain whether these skills represent two separate but related constructs across the adult lifespan (as found by Hegarty et al., 2006, but only in young adults) or whether they are parts of a single general spatial ability factor. Judging from initial evidence of age-related differences in spatial abilities and spatial self-assessments (Borella et al., 2014), we would expect to see the two-factors model extend to a lifespan perspective too. It is worth noting that different self-assessment measures were considered together here for the first time, including sense of direction, pleasure in exploring, spatial anxiety, and pleasure in visiting known places, and it may be that these variables represent not one single factor but several different sub-factors.

Second, different models tested how age, WM, spatial abilities and spatial self-assessments are related to performance in pointing in cardinal directions. Given the well-established relationships between age and WM (e.g. Borella, Ghisletta, & de Ribaupierre, 2011), and between WM and spatial abilities (Miyake et al., 2001), and given some evidence of a relationship between WM and spatial self-assessments (Baldwin & Reagan, 2009), in our Model 1 – based on the SEM approach (see Fig. 2) – we expected age to have a direct link to WM, which in turn may mediate age-related variance in both spatial abilities and spatial self-assessments. Further, given the positive relationships between age and spatial abilities (Borella et al., 2014; Kirasic, 2000), and between age and spatial self-assessments (Borella et al., 2014; Pazzaglia & De Beni, 2006), we explored whether age also influenced these factors directly. Spatial abilities and spatial self-assessments were expected to have a direct influence on environment orientation task performance (as suggested by Hegarty et al. (2006) in young adults, and by Kirasic (2000) in older adults). We therefore explored whether age-related effects on performance in pointing in cardinal directions are mediated by spatial skills (measured objectively and subjectively), which are in turn influenced by age and WM. Since the relationship between age, WM, and pointing in cardinal directions had yet to be examined, we also tested whether pointing performance was influenced directly by age, and also whether WM is related directly to pointing performance (in Models 2 and 3, respectively).