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When young and older adults learn a map: The influence of individual visuo-spatial factors

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ABSTRACT

The present study explores how age and individual visuo-spatial factors influence the processes underlying spatial mental representations derived by learning from a map. Forty young adults (24–35 years old) and 40 older adults (65–75 years old) were assessed on visuo-spatial abilities and self-assessed spatial preferences. Then they studied a map of a botanical garden and were asked to place a list of landmarks on a sketch. When missed locations were considered in calculating accuracy, older adults were less accurate than young adults, and accuracy was predicted by age and a preference for exploring new environments. When only the landmarks placed in the sketch were considered, however, older adults were as accurate as young adults, and accuracy was predicted only by visuo-spatial working memory. These findings show that spatial representations have features differently predicted by age and visuo-spatial factors, and are discussed in the light of aging and spatial neurocognitive models.

1. Introduction

Getting to know an environment is an experience typical of every stage of human life, from when children crawl to reach a toy under the chair to when the elderly go to their local pharmacy. The ability to remember the positions of objects or salient landmarks and how they relate to one another and to other features of the environment is associated with the formation of a mental map (Tolman, 1948), i.e., an internal representation of the layout of an environment that enables a flexible management of environmental information, such as landmarks and their relationships (Wolbers & Hegarty, 2010). Various factors are capable of modulating an individual's environment knowledge acquisition (Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006; Wolbers & Hegarty, 2010). Some of them are external, such as the type of input used to present spatial information (a map, verbal instructions, navigation); others are internal, and include age, i.e., young vs. older adulthood (differences have been identified between young adults in their twenties or thirties and adults in their sixties or more; Baltes & Staudinger, 2000), and individual visuo-spatial factors (such as visuo-spatial abilities and self-assessed spatial preferences). It is important to consider these factors, alone and in combination, when analyzing environment knowledge acquisition and how people's performance varies, even in old age (Shelton, Marchette, & Furman, 2013). The present study comes within this field of research and specifically focuses on: i) the map as a source of learning with the analysis of the underlying processes involved in mentally representing spatial information in young and older adults; and ii) how individual visuo-spatial factors support this mental representation.

Maps are commonly used to acquire spatial knowledge. They organize information allocentrically, showing landmarks and paths connecting them (as used in studies on young adults, e.g., Richardson, Montello, & Hegarty, 1999; Thorndyke & Hayes-Roth, 1982). Maps reproduce large areas, such as a city or garden, on a small scale with respect to an individual's body and a single viewpoint is experienced. For these reasons, following Montello's (1993) definition, they can be considered as a figural space source, which differs from other media that are larger than the body and require the integration of information over time (as when navigating in environmental spaces). Studies use maps not only to assess people's ability to orient themselves in an environment (when, for instance, participants are shown a map and then asked to go along a path, e.g., Wilkniss, Jones, Korol, Gold, & Manning, 1997), but also to analyze the cognitive processes involved in their map learning and how landmarks are arranged on their mental maps (Borella, Meneghetti, Muffato, & De Beni, 2015; Coluccia, 2008; Coluccia, Bosco, & Brandimonte, 2007). With aging, people become less able to develop such mental maps and neurocognitive models suggest that this is due to an age-related deterioration in the hippocampus. This is the area of the brain most involved both in a mental map's formation (Bird & Burgess, 2008; O'Keefe & Nadel, 1978) – in the anterior part, and in its storage – in the posterior part (for a review, see Lithfous, Dufour, & Després, 2013).

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Given the map-learning difficulties associated with aging, adopting an allocentric modality to present spatial information (e.g., showing a map) can prompt the formation of a cognitive map that poses fewer problems in terms of switching between views – to convert information from a path-following view to a configurational (allocentric) view, for instance. The literature indicates that the use of maps in aging studies thus seems to be less liable to age-related effects than when other types of input are used, such as navigation (e.g., Yamamoto & DeGirolamo, 2012), or spatial descriptions (e.g., Meneghetti, Borella, Grasso, & De Beni, 2012); age-related differences in map learning are influenced by multiple factors, however, such as the type of recall task used. Older adults nevertheless have more difficulty than young adults when asked to manage information learned from a map. In fact, after learning from a map, older adults perform less well than young adults when they need to imagine adopting different positions on the map (in pointing tasks), or when the format of their answer changes, such as when they answer questions about the spatial relations between landmarks (verification tests; e.g., Borella et al., 2015; Meneghetti, Muffato, Suitner, De Beni, & Borella, 2015).

Older adults may find things easier when the information encoded in a map is retrieved in the same format, i.e., when they are asked to freely draw a map of the environment (freehand map drawing task) or to position landmarks in a skeletal layout of the environment (sketch map task; Blades, 1990; Rovine & Weisman, 1989). In these types of task, the format (visuo-spatial) and the action (locating landmarks in relation to one another) match with the input used in the learning phase (the map). This avoids older people experiencing the cognitive overload that occurs when they are faced with other types of task and demand (e.g., Meneghetti, Borella, Gyselinck, & De Beni, 2012). Studies using graphical reproductions of environments (as in the freehand map drawing or sketch map tasks) have generated inconsistent results, however. There have been some reports of a similar performance in young and older adults (e.g., Meneghetti, Borella, Grasso, et al., 2012; Yamamoto & DeGirolamo, 2012), while others found an impaired performance in older adults (e.g., Meneghetti, Fiore, Borella, & De Beni, 2011; Meneghetti et al., 2015; Wilkniss et al., 1997). One of the reasons for these discrepancies could lie in the processes underlying spatial information recall (as demanded by different requests in a map drawing task). Indeed, spatial memory is not a unitary construct. We can distinguish between its function in landmark processing (i.e., object identity memory, Postma, Kessels, & Van Asselen, 2004), in exact, metric (Euclidean), coordinate processing (i.e., positional memory; McNamara, Hardy, & Hirtle, 1989), irrespective of the identity of an object, and its function in forming associations between the identity of objects and their positions (i.e., object-location memory; Kessels, Kappelle, de Haan, & Postma, 2002). Therefore landmark identity memory, positional memory and landmark-location binding represent different processes that can be highlighted when assessing the results of map drawing tasks. For instance, some studies considered map drawing accuracy in terms of the landmarks positioned correctly, as on a previously-learned map, noticing any landmarks that were wrongly positioned or omitted (e.g., Meneghetti et al., 2011; Moffat & Resnick, 2002). Other studies (based on a bidimensional regression method, Friedman & Kohler, 2003) explored to what degree the layout reproduced in the map drawing was distorted with respect to the original map learned (e.g., Yamamoto & DeGirolamo, 2012), and any missed locations were disregarded. Thus, considering landmark positioning with or without taking locations that are missing into account can measure different memory processes. In the former case, when missed locations are taken into account, the accuracy score is related more to memory, i.e., to the respondent's ability to remember positions. In the latter, when only the accurate positioning of the landmarks recalled is considered, the score can reflect the representation of the landmarks in relation to one another, i.e., the respondent's ability to associate the landmarks with their locations. Therefore, when we consider missed locations in judging accuracy, this may be a measure of positional memory, i.e., how many positions can be recalled, whereas if we consider only the landmarks placed on the map, then we are measuring accuracy in terms of object-location memory. These spatial memory processes rely on networks with different brain regions as major hubs, however: positional memory depends largely on the part of the hippocampus in the right hemisphere, while object-location memory relies on the hippocampus to some degree (mainly on the part in the left hemisphere) while other brain regions (such as the prefrontal cortex) are more strongly implicated (see Kessels, de Haan, Kappelle, & Postma, 2001 for a meta-analysis; Kessels, Hobbel, & Postma, 2007). In the light of the above assumptions, using different indices to measure recall accuracy in map recall tasks, with and without taking missed locations into account, can shed more light on participants' spatial representation capabilities (i.e., their positional and object-location memory), and thus on what is preserved or liable to decline in older adults.

Given that sketch map task can reveal different constructs of spatial memory, it is important to bear in mind other aspects capable of helping to explain how spatial learning accuracy can vary. One such aspect is the individual visuo-spatial factor, as emerged in studies on young adults (Hegarty et al., 2006; Weisberg, Schinazi, Newcombe, Shipley, & Epstein, 2014). The term 'visuo-spatial' refers to a whole set of factors, including: the ability to retain and process visuo-spatial information (visuo-spatial working memory, VSWM); spatial cognitive skills, such as the ability to generate, retain and transform abstract visual images (Lohman, 1988), which is multi-faceted, like mental rotation and perspective-taking abilities; and also individual preferences and strategies employed to learn and represent an environment (as ascertained by means of visuo-spatial self-assessments). Studies have shown that, although VSWM and visuo-spatial abilities decline with aging (Borella, Meneghetti, Ronconi, & De Beni, 2014; Techentin, Voyer, & Voyer, 2014), they sustain the environment representations of both young and older adults (e.g., Meneghetti, Borella, Muffato, Pazzaglia, & De Beni, 2014). As concerns map learning, Borella et al. (2015) showed that: mental representations derived from map learning become extremely orientation-dependent with aging; and VSWM correlates with map learning accuracy – consistently with studies on young people showing a relationship between working memory (WM) and map learning (Coluccia, 2008; Coluccia et al., 2007) –. Map learning accuracy correlates with visuo-spatial (rotation) skills in young and older adults (as assessed using rotation tasks, e.g., Meneghetti et al., 2011), and these individual factors can mediate the relationship between age and environment knowledge (Kirasic, 2000; Meneghetti, Borella, Pastore, & De Beni, 2014). Meneghetti, Borella, Pastore, et al. (2014) showed, for instance, that visuo-spatial (rotation) abilities, VSWM and self-assessments mediate the relationship between age and the ability to orient oneself in an environment (using cardinal points). As introduced in the above-mentioned study, another individual factor to take into account concerns visuo-spatial preferences. Self-reported spatial cognitive style (Nori & Giusberti, 2003; Pazzaglia & Moè, 2013), sense of direction, spatial anxiety, and attitudes to novel environments all need to be considered in older people, as well as in young adults (e.g., Hegarty et al., 2006). Self-reported attitudes and preferences are relevant to performance in spatial tasks (Meneghetti, Borella, Pastore, et al., 2014; Salthouse & Mitchell, 1990). There is evidence of older adults' sense of direction (De Beni, Meneghetti, Fiore, Gava, & Borella, 2014; De Beni, Pazzaglia, & Gardini, 2006) correlating positively with their spatial learning (De Beni et al., 2014), even if a map is used as a source of information (De Beni et al., 2006). As for spatial anxiety, i.e., the self-reported level of worry when faced with spatial problems (such as having to find a certain place), it is demonstrated that this negatively affects spatial performance, in young adults at least (Lawton, 1994; for map learning: Thoresen et al., 2016), while its role when older adults learn from maps is less well known.

To sum up, administering map drawing task after participants have studied a map can offer insight on the underlying process of people's mental representations with aging. In particular, the