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The joint role of spatial ability and imagery strategy in sustaining the learning of spatial descriptions under spatial interference[☆]

Chiara Meneghetti [a,*], Rossana De Beni [a], Valerie Gyselinck [b], Francesca Pazzaglia [a]

[a] Department of General Psychology, University of Padua, Italy

[b] Laboratoire Mémoire et Cognition, Université Paris Descartes, France

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ABSTRACT

The present study investigates the joint role of spatial ability, imagery strategy and visuospatial working memory (VSWM) in spatial text processing. A set of 180 participants, half of them trained on the use of imagery strategy (training vs no-training groups), was further divided according to participants' high or low mental rotation ability (HMR vs LMR). Each group listened to environment descriptions and performed recall tasks before and immediately after training/no-training, and again after listening to a text while performing a spatial tapping task. Visuospatial and verbal tests were also administered. Our results showed that HMR had a better spatial profile than LMR participants, and that only LMR participants benefited from training and showed the interference effect. Overall, our findings indicate that a good spatial ability reduces the spatial interference effect and that poor spatial ability, which is related to the spatial interference effect, can be partially compensated by learning imagery strategy.

1. Introduction

In everyday life, one way to convey environmental information is to use descriptions. A person looking for a given destination may, for instance, identify it by reading a tourist guide book illustrating the path to take or by asking someone on the street for spatial directions. The readers or listeners usually reach the right destination if they construct a mental representation of the environment described. The result is a mental model (Johnson-Laird, 1983; van Dijk & Kintsch, 1983) in which spatial content is represented, preserving the physical properties of space, such as the relative relationships between objects (Perrig & Kintsch, 1985; Taylor & Tversky, 1992) and information about distances (Rinck, Hahnel, Bower, & Glowalla, 1997).

In the last decade, a number of studies have focused on analyzing the cognitive functions, such as working memory (WM), involved in the construction of mental representations from spatial descriptions (of an environment). WM involvement in processing spatial descriptions has also been investigated in relation to spatial ability or imagery strategy, but how these aspects work together remained unexplored. The novel goal of the present study was to shed light on how spatial ability and strategy interact in the processing of spatial descriptions, analyzed in relation to WM.

1.1. Spatial descriptions and WM involvement

A first line of research analyzed the role of temporary memory functions in sustaining spatial description processing. Baddeley's WM model (1986; Baddeley & Hitch, 1974) enables this experimental question to be approached. According to this model, WM is considered as a temporary storage and processing system with a central component (i.e. the central executive) responsible for controlling two sub-components, one verbal (VWM) for maintaining and processing verbal information, and the other visuospatial (VSWM) for maintaining and processing spatial and visual information. The paradigm typically used is the dual-task, which involves performing a primary task (e.g. hearing or reading a text) concomitantly with a secondary task (e.g. repeating syllables). If the secondary task competes for the same limited WM resources, primary task performance deteriorates by comparison with the single-task condition.

Using the dual-task paradigm, several studies have shown the specific involvement of VSWM in processing spatial sentences/descriptions (De Beni, Pazzaglia, Gyselinck, & Meneghetti, 2005; Noordzij, van der Lubbe, Neggers, & Postma, 2004; Pazzaglia & Cornoldi, 1999; see Gyselinck & Meneghetti, 2011 for a review). De Beni et al. (2005) asked participants to listen to non-spatial and spatial descriptions (describing an outdoor route from the person's point of view) while performing a verbal task (articulatory suppression [AS], consisting in the repetition of sets of syllables), and a spatial task (spatial tapping [ST], which involved tapping on four buttons located in the corner of a board) at the same time. The participants' recall of the descriptions (tested using the verification test—i.e., to answer to true/false spatial questions—and free recall) was considered a measure of the interference effect on the primary task. The study showed that performing AS while

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* Corresponding author at: Department of General Psychology, Via Venezia, 8, 35131 Padova, Italy. Tel.: +39 049 8276911; fax: +39 049 8276600.
E-mail address: chiara.meneghetti@unipd.it (C. Meneghetti).

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listening to the descriptions weakened recall of both non-spatial and spatial descriptions, while performing ST only interfered with the recall of spatial descriptions. This indicates that VSWM specifically underpins the memorization of spatial description content and this result was amply confirmed by further studies analyzing other, complementary aspects (encoding vs retrieval, Pazzaglia, De Beni, & Meneghetti, 2007; the time spent listening to the text, Meneghetti, De Beni, Gyselinck, & Pazzaglia, 2011; spatial perspective, Brunyé & Taylor, 2008; Deyzac, Logie, & Denis, 2006; Pazzaglia, Meneghetti, De Beni, & Gyselinck, 2010) in which recall was also tested using a spatial measure such as a graphical representation.

1.2. Spatial descriptions, WM and spatial ability

A second question of particular interest is whether certain cognitive aspects support spatial text processing, examined in relation to WM. One of the aspects found to have a central role is spatial ability, i.e. the ability to generate, retain and transform abstract visual images (Lohman, 1979). Spatial ability is important in environment learning (e.g. Allen, Kirasic, Dobson, Long, & Beck, 1996; Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006) even when spatial information is acquired from descriptions (Bosco, Filomena, Sardone, Scalisi, & Longoni, 1996; de Vega, 1994). A number of studies have focused on one of the various spatial abilities (Linn & Petersen, 1985), mental rotation (MR), which measures the ability to rotate 2- or 3-dimensional stimuli; this particular skill has proved fundamental to environment learning (e.g. Fields & Shelton, 2006) even when spatial descriptions are used (Pazzaglia, 2008).

To analyze how spatial text processing, WM and spatial ability work together, we recently conducted a study (Meneghetti, Gyselinck, Pazzaglia, & De Beni, 2009) in which we asked participants with a high and low mental rotation ability (HMR and LMR, respectively)—selected with the Mental Rotations Test (MRT; Vandenberg & Kuse, 1978)—to listen to non-spatial and spatial descriptions while performing AS or ST tasks at the same time. The results showed that spatial text recall was damaged by both concurrent tasks only in LMR (not in HMR) individuals; while both group's performance in non-spatial text recall was disrupted only by AS. HMR individuals preserved the ability to manage spatial description information in the dual-task condition, but both HMR and LMR participants were slower at ST in the dual-task than in the single-task condition, and this is considered an indicator of VSWM involvement (see also Gyselinck, De Beni, Pazzaglia, Meneghetti, & Mondoloni, 2007). These findings indicate that LMR individuals are disadvantaged when recalling spatial descriptions in the dual-task condition, finding it difficult to handle two spatial tasks at the same time, while HMR individuals are better able to handle more spatial information even if they are supported by VSWM (see Meneghetti, De Beni, Pazzaglia, & Gyselinck, 2011; and Pazzaglia, Gyselinck, Cornoldi, & De Beni, 2012 for a review).

What remained to be seen was how spatial ability interacts with the use of imagery strategy and this is a matter of particular interest to elucidate whether a poor ability can be compensated, at least in part, by using appropriate visuospatial strategies to process spatial descriptions. This is an interesting question but no evidence has been collected on the issue as yet. We did obtain some information, however, on what happens when individuals are trained specifically to use visuospatial strategies while processing spatial descriptions in the dual-task condition.

1.3. Spatial descriptions, WM and visuospatial strategies

It is widely recognized that strategies like the use of visual images can increase the recall of verbal material, such as lists of words, sentences and texts (e.g. Campos, Gomez-Juncal, & Perez-Fabello, 2009; De Beni & Moè, 2003; Richardson, 1998). In the case, for instance, of people who have listened to a spatial description or directions on a route, using mental images enables them to form a mental representation, to construct a mental image depicting spatial relationships between landmarks (as suggested by de Vega, Cocude, Denis, Rodrigo, & Zimmer, 2001; Struiksma, Noordzij, & Postma, 2009). When individuals report using strategies based on mental images, they construct better mental representations of an environment than individuals who claim to have not used such strategies (Meneghetti, De Beni, Gyselinck, & Pazzaglia, 2011). Given the efficacy of using such strategies, some studies showed that training individuals to use imagery strategy improved their recall of verbal material by comparison with an untrained control group (e.g. Carretti, Borella, & De Beni, 2007; da Silva & Yassuda, 2009). We still know very little, however, about the positive effect, if any, of adopting such a strategy to recall spatial description of an environment.

The use of visual images is supported by a VSWM component (see Pearson, 2001). Experimental evidence has shown that VSWM is specifically involved when mental images are used to process visuospatial material, such as the Brooks Matrix (Quinn & Ralston, 1986), visual patterns (Logie, 1986), or words (Quinn & McConnell, 2006).

To explore how the use of mental images and VSWM work together to sustain the processing of spatial descriptions, Gyselinck and colleagues (Gyselinck, Meneghetti, Pazzaglia, & De Beni, 2009; Gyselinck et al., 2007) asked participants to listen to spatial descriptions, alone or in association with AS or ST; they had previously been instructed (Gyselinck et al., 2007) or trained (Gyselinck et al., 2009) to use mental images or a repetition strategy. Results showed that the imagery group generally had a better spatial recall than the repetition group in the single-task condition. In the dual-task condition, the imagery group's spatial recall was more damaged by ST than the repetition group's; and both strategy groups' recall was disturbed by AS (Gyselinck et al., 2007, 2009). Moreover, the participants' rhythm in ST and AS changed from the single- to the dual-task condition (Gyselinck et al., 2007). These results demonstrate the involvement of VSWM in processing spatial descriptions, especially when people use mental images.

Nonetheless, it remains unclear how imagery strategy interacts with spatial ability in processing spatial descriptions in the dual-task condition. Preliminary evidence was obtained by Gyselinck et al. (2009; second part of the study): in LMR individuals trained to use mental images, spatial recall was especially damaged by AS and ST, while LMR and HMR groups trained to use a repetition strategy were only affected by AS. These results suggest that spatial competences (spatial ability, imagery strategy and VSWM) positively cooperate to process spatial descriptions, but these findings cannot be generalized due to the study's limitations, which included a small number of participants (only 6 or 7 in each LMR or HMR group) and the experimental design (which made it impossible to measure within-participant improvements in spatial text recall from the baseline—before training—to after the training and then during ST).

To complete the picture within this frame of studies, it is important to understand how spatial ability and imagery strategy work together in sustaining spatial text processing in the dual-task condition. If we take the case of individuals who have a poor spatial ability, it is not entirely clear whether using imagery strategy can help them to reduce the spatial interference effect, or whether this strategy is insufficient for coping with spatial interference. At the same time, individuals with good spatial abilities can benefit from imagery strategy too.

1.4. Aims of the present study

The present study aimed to investigate the joint role of spatial ability, visuospatial strategy and VSWM in spatial text processing. The shortage of knowledge of how spatial ability and imagery strategy work together, and whether one or both have a prominent role in sustaining spatial text processing when VSWM is overloaded by the concomitant performance of the ST task is specifically approached in this study. Two learning conditions were planned to look into this