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One's own country and familiar places in the mind's eye: Different topological representations for navigational and non-navigational contents

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HIGHLIGHTS

- Distinct strategies are used to solve different types of mental images.
- Subjects used horizontal perspective for campus and vertical for clock and Italy.
- Differences in vividness of mental images affect the contents of mental images.
- Preferences for verbal versus visual strategies affect the contents of mental images.
- Imagining a familiar navigational space differs from imagining a geographical space.

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ABSTRACT

Visual mental imagery is a process that draws on different cognitive abilities and is affected by the contents of mental images. Several studies have demonstrated that different brain areas subtend the mental imagery of navigational and non-navigational contents. Here, we set out to determine whether there are distinct representations for navigational and geographical images. Specifically, we used a *Spatial Compatibility Task* (SCT) to assess the mental representation of a familiar navigational space (the campus), a familiar geographical space (the map of Italy) and familiar objects (the clock). Twenty-one participants judged whether the vertical or the horizontal arrangement of items was correct. We found that distinct representational strategies were preferred to solve different categories on the SCT, namely, the horizontal perspective for the campus and the vertical perspective for the clock and the map of Italy. Furthermore, we found significant effects due to individual differences in the vividness of mental images and in preferences for verbal versus visual strategies, which selectively affect the contents of mental images. Our results suggest that imagining a familiar navigational space is somewhat different from imagining a familiar geographical space.

1. Introduction

Visual mental imagery arises when perceptual information is accessed from memory, giving rise to the experience of "seeing with the mind's eye" [1,2].

This cognitive process draws on many abilities, which rely on different cerebral structures [3] depending on the contents of the image. For example, imagining a face, an object or a place produces activation in different brain areas [4–6].

When people have to arrange the parts of a mental image [7,8], they process them using categorical and/or coordinate strategies. In categorical processing judgements have to be made about the relative position of the components of a visual stimulus, and in coordinate processing absolute distances have to be calibrated between the components of a visual stimulus [9]. Palermo et al.

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[10] found that people rely exclusively on categorical processing to generate mental images of common objects, but require both coordinate and categorical processing to generate mental images of landmarks. Furthermore, individuals can be classified as visualizers or verbalizers according to whether they rely on imagery when performing cognitive tasks or on verbal–analytical strategies, respectively [11]. Visualizers mainly process images using coordinate strategies, whereas verbalizers mainly adopt categorical strategies when they have to analyze parts of a mental image [12].

Representational neglect [13], a syndrome which affects the mental representation of space following a cerebral lesion, can selectively affect different imagery domains, that is, patients can show deficits in imagining environments and/or objects [14,15].

Guariglia and Pizzamiglio [16,17] proposed the existence of two different types of mental representations of space: "topological" (navigational) and "non-topological" (non-navigational) images. The first are defined as mental representations of stimuli in which it is possible to navigate, and the latter as representations of objects or visuo-spatial displays in non-navigational space (i.e., whether or not I can navigate in the space, regardless of its distance). A second reading of cases with representational neglect and a recent group study [15] support this distinction. Ortigue and co-workers [18] reported the case of a patient with representational neglect that selectively compromised the far space of a mental representation. When asked to imagine her near space, the patient made no detectable omissions on the contralesional side of the mental image. By contrast, when asked to bring back memories of a familiar square in Geneva and of the map of France she "forgot" elements that fell on the left side of the mental representation. Grossi and coworkers [19] described another patient who failed when he had to mentally compare two different times on two analogue clocks to decide which clock hands formed the widest angle; thus, he showed a deficit in the mental representation of an object.

It has, however, been highlighted that both navigational and non-navigational mental images can be defined according to viewer-centred and object-centred coordinates [20]. Viewer-centred coordinates involve the ability to locate objects with reference to one's own body, whereas object-centred coordinates determine where something lies in the world regardless of one's position. It can be hypothesized that topological mental images about navigational space rely mainly on a viewer-centred coordinates, whereas mental images of non-navigational objects rely mainly on object-centred coordinates. Indeed, people navigate through the processing of spatial relations among objects by linking them to their own position, thus adopting a viewer-centred perspective. Depending on task requirements, however familiar places might also be represented through an object-centred coordinates. For instance, if an examiner asks a subject to mentally represent the distance between two landmarks, the viewer-centred perspective is not required, even though the individual has already directly experienced the environment in a viewer-centred perspective to make such an estimation. Furthermore, to know what time it is, subjects process the spatial relations between objects using the spatial relations between the hands of the clock, thus adopting an object-centred perspective. Representing the map of one's own country is more similar to object representation, as it is also based on an object-centred perspective. This issue raises some concerns, especially regarding the use of geographical space to assess representational neglect, because geographical and proper navigational space may tap into different mental representation processes. Nevertheless, it is very difficult to establish whether object-centred or viewer-centred coordinate systems make the difference in mentally representing navigational and non-navigational images. This is especially true in the case of geographical maps, which also provide navigational information. Moreover Ortigue and co-workers [18] described a patient who showed a clear deficit in representing both a familiar square in Geneva and the map of France. This suggests that there is a relationship between mental images of geographical and navigational spaces. Differently, Rode and co-workers [21] reported a case in which geographical information had to be spatialized to be neglected. In their study, evocation strategies appeared very different when distances between successively named towns were considered. When the task was to form a visual image of the map, the patient's performance was severely impaired; by contrast, the patient performed without hesitation when he had to list the names of towns in France without imagining placing them on the map.

A study aimed at investigating which strategies healthy participants use in representing different navigational and non-navigational mental images might be useful to better understand the mechanisms underlying the mental representation of space and objects. Furthermore, in light of the disagreement in the current literature over the frequency of representational neglect, with some studies reporting that neglect confined to visual mental imagery is a rare occurrence [22,23] and others reporting higher frequencies for it [15], it might be useful to understand whether its presence was underestimated due to a bias in the tasks used for assessment. Bartolomeo et al. [23] hypothesized that a task-dependent bias was present in the "memory after description" condition proposed by Denis et al. [24]. In this condition the authors presented patients' visual layouts or verbal descriptions of layouts and then asked them to recall the material. Indeed, in this task healthy participants also showed a tendency to report fewer items on the left than on the right.

As different mental imagery domains exist [16,17], neuropsychological evaluation of representational neglect might fail to find representational deficits because it was not directly assessed. We aimed to determine whether distinct domains exist for different mental images, especially due to the possibility to navigate across them. Other then comparing clearly navigational and non-navigational mental images, we tested for the first time the hypothesis that the mental image of geographical space, which conveys navigational information but cannot be properly navigated, is represented similarly to the mental image used in representing a familiar object. Specifically, we investigated whether processing a navigational mental image of a geographical space (i.e., the map of Italy) corresponds to processing a non-navigational mental image (i.e., the clock) or a navigational mental image (i.e., the campus). Results should be interesting because of the differences reported in neuropsychological case reports and the frequency of representational neglect. For this purpose we developed three different conditions in which we compared navigational versus non-navigational images using well-defined and comparable tasks. Furthermore, we assessed the presence of individual differences in using strategies to arrange the parts of different mental images. In light of previous findings [10] it is important to better understand whether individual predispositions to use categorical or coordinate spatial relations affect mental imagery domains differently.

2. Materials and method

2.1. Participants

Twenty-one healthy right-handed students at the Sapienza University of Rome, very familiar with the campus (i.e., for at least three years) (mean age 27.33 ± 3.97; 12 females) without neurological or psychiatric disorders, participated in the study. Their campus knowledge was assessed by a preliminary questionnaire in which they were asked to locate the campus landmarks on a map (mean *landmark knowledge* of the university campus