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Short-term Memory Representation Of A Complex And Non-familiar Environment After Brief Exposure

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Abstract

The processes in the brain which enable humans to navigate independently through complex environments have been related to functionally identified neural structures involved in long-term memory representation. This study investigates the role of short-term memory representation, activated through brief exposure to the spatial layout of an unfamiliar complex environment. The effects of short-term memory processes on navigation performances of men and women were investigated. After two minutes of either 2D map or direct viewing (learning phase), individuals navigated from memory in Google Street View (test phase). Subjective ratings of psychological stress were recorded after testing. Satisfactory, and significantly better navigation performances compared with 2D map exposure, were found for both men and women after direct viewing. A significant effect of the sex factor was observed after 2D map exposure, where women produced the weakest performances, and the highest psychological stress ratings. We conclude that short-term memory representations of a complex and novel spatial layout enable successful navigation, depending on the type of visual information made available through prior exposure. Direct visual experience is encoded more effectively by the brain than abstract map experience, especially by women, under the conditions

Introduction

Cognitive mapping processes relate to the transformations by which the brain encodes, stores, retrieves, and decodes information about local and global characteristics of space. The seminal work by Tolman on cognitive maps in rats and men [1] has provided most of our current insight into the processes of attention and spatial perception which enable the selection and brain representation of spatial information for navigation. Long-term brain representations of routes, directions, landmarks, and regions constitute what Tolman (1948) referred to as the cognitive maps of our physical environment.

Cognitive maps are related to functionally identified long-term memory structures in the brain [2], and current theory suggests that they are constructed hierarchically through different levels of learning, grouping local features of complex spatial layouts into different levels of representation for a global understanding of space [3]. Short-term memory processes are likely to play an important role in this processing hierarchy, although surprisingly little is known about its relative contribution to the ability of humans to navigate independently through complex and novel environments. Short-term memory representations encoded from a visual experience need to be translated into meaningful representations of action and event sequences to allow an individual to navigate successfully, and the use of landmarks remembered is a critical variable in this process [4]. Abstract conceptual information relative to space, such as local and global configurations of routes and their geometry, is conveyed through two-dimensional (2D) visual maps. Being able to exploit the abstract geometry of 2D maps for navigation requires complex transformations in the brain generating meaningful correspondences between the two-dimensional metric and perceived three-dimensional characteristics of the actual environment. Results from a recently published study [5] suggest that women could have greater difficulty than men in realizing such transformations. While there is no doubt that women can become excellent navigators, it would be important to gain a better understanding of the possible origin of this result, which can be linked to previous observations reporting sex differences in navigation strategies [6, 7]. The goal of the present study was to determine whether short-term memory representations of a complex and unfamiliar spatial layout, encoded from a brief 2D visual map experience or from equally brief direct visual viewing, enable men and women to navigate successfully.

Materials and Method

Men and women were tested in a navigation task after a brief exposure (2 minutes) to either a 2D visual map, or single trial direct viewing (2 minutes) of their itinerary, leading from a departure point to a target

location through streets of Paris in Google Street View. **Subjects:** 52 individuals (27 men and 25 women) participated in the study as subjects. Their age varied between 23 and 63 years and all of them were professionally active. It was made sure that all of them were familiar with using a computer, but none was particularly experienced in using Google Street View, or had knowledge of the location of the itinerary studied. **Apparatus:** Experiments were run on a PC (DELL) equipped with a 19" color screen and a mouse for navigating. A website was created using the Open Source CMS (Content Management System) Joomla 1.0.15. The website ensured content management for an entire individual session, from the instructions given to the participant to all the parameters recorded during navigation with Google Street View, including individual subjective ratings of stress levels. Google Street View, an 'online' tool that allows users to navigate through virtual representations of the streets of major cities, was accessed directly from this website. **Procedure :** Participants were seated in front of the computer screen and logged into the CMS with an individual password, which was communicated to them before the experiment. A supervisor was constantly present in the background to clarify issues that were not understood or remained unclear to the participant. 27 of the participants (fourteen men and thirteen women) were exposed to a 2D route map of the itinerary on the computer screen for two minutes. All were instructed to memorize the itinerary for subsequent navigation. Test navigation was terminated when the participant deemed that he/she had reached the target location. The other 25 participants (thirteen men and twelve women) were given a direct viewing experience for two minutes in Google Street View. All were instructed to memorize the itinerary for subsequent navigation. After the test phase, individuals were given a landmark memory test and were asked to rate their subjectively experienced psychological stress or anxiety during task execution on a scale between -10 and +10. It was explained to them that -10 was to indicate optimal relaxation, 0 was to indicate indifference to or uncertainty about any stress or anxiety, and +10 was to indicate maximal psychological stress or anxiety.

Results

The effects of the type of prior exposure and the sex variable on navigation times, success rates (percentage of correct turns) and subjective psychological stress during task execution were analyzed. Analyses of variance (ANOVA) were

performed. Navigation times were significantly shorter ($F_{(1,2)}=17.20$, $p<.001$) and success rates significantly higher ($F_{(1,2)}=14.45$, $p<.001$) after direct experience compared with 2D map exposure. The navigation times of women were significantly higher ($F_{(1,2)}=5.35$, $p<.05$) and their success rates significantly lower ($F_{(1,2)}=3.35$, $p<.05$) compared with those of the men after 2D map exposure. Interestingly, womens' success rates were noticeably, but not significantly, higher than those of the men after direct experience. Results from the post-test landmark memory task showed that individuals remembered more landmarks after having been tested in the direct experience condition. Subjective ratings of the psychological stress experienced by individuals were significantly higher after 2D map exposure ($F_{(1,2)}=11.89$, $p<.001$) compared with direct experience. Test navigation after 2D map exposure produced the highest stress ratings, with levels twice as high in women compared with those of the men. The highest psychological stress ratings were produced by women in the age range between 40 and 63 years, the lowest ratings by men in the same range. Standard deviations of the stress ratings signal considerable inter-individual variations within all age groups. Table 1 here below gives an overview of the average data and standard deviations.

Table 1

Test navigation after direct experience	men (N=14) age range: 25 to 63	women (N=13) age range: 23 to 55
Time (seconds)	mean: 315 std: 108 min: 181 max: 600	mean: 361 std: 120 min: 180 max: 540
Success rates (% correct)	mean: 90% std: 26 min: 0% max: 100%	mean: 97% std: 6.3 min: 80% max: 100%
Subjective stress rating	mean: 0 std: 5.8 min: -10 max: +6	mean: -5.5 std: 7.6 min: -10 max: +8

Test navigation after 2Dmap exposure	men (N=13) age range: 23 to 60	women (N=12) age range: 25 to 48
Time (seconds)	mean: 438 std: 174 min: 240 max: 910	mean: 584 std: 186 min: 300 max: 840
Success rates (% correct)	mean: 69% std: 41 min: 0% max: 100%	mean: 53% std: 42.7 min: 0% max: 100%
Subjective stress rating	mean: +1.5 std: 5.9 min: -8 max: +8	mean: +3.7 std: 5.7 min: -8 max: +10

Discussion

The findings reported here show that short-term memory representation of spatial layout, encoded from very brief prior visual experience, generates brain data that are reliable for independent navigation through a complex and novel environment without aid or other guidance. The greater efficiency of representations encoded from direct experience is consistent with conclusions from studies on long-term memory effects in real-world navigation, where prior direct experience systematically enables the best performances [8]. Functional imaging studies have shown that spatial knowledge for navigation is encoded in long-term memory circuits of the human brain, which respond to virtual environments in the same way as they do to real environments, are highly plastic, and connect to visual short-term memory structures [4]. In the light of the present data, we conclude that the short-term encoding of temporary brain representations of space for navigation is an important step in the hierarchical construction of long-term spatial memory. Memory function has evolved across the species to generate increasingly efficient adaptive behaviours. It makes good sense to assume that interactions between short- and long-term memory processes [9], especially in navigation, enable the continuous updating of brain data relative to physical space and are thus essential to our survival in a continuously changing environment. Sex differences in the ability to encode short-term spatial representations from abstract 2D maps for successful navigation are likely to be epigenetically determined. Increased anxiety was previously found to correlate with lesser spatial matching ability [7]. We believe that it is likely to be a consequence of the greater psychological stress associated with transforming abstract 2D information into meaningful sequences of events. Although the age factor had no significant influence in this study, there are hints that the psychological stress of women and men in spatial tasks could be a complex differential function of age, with a tendency to diminish with increasing age in men and to augment with age in women.

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