Cogn Process
DOI 10.1007/s10339-015-0668-y

SHORT REPORT

The effect of repetition priming on spatial memory during backtracking in a novel environment

Michal Mukawa[1] · Cheston Tan[1] · Joo-Hwee Lim[1] · Qianli Xu[1] · Liyuan Li[1]

Abstract During wayfinding in a novel environment, we encounter many new places. Some of those places are encoded by our spatial memory. But how does the human brain "decides" which locations are more important than others, and how do backtracking and repetition priming enhances memorization of these scenes? In this work, we explore how backtracking improves encoding of encountered locations. We also check whether repetition priming helps with further memory enhancement. We recruited 20 adults. Each participant was guided through an unfamiliar indoor environment. The participants were instructed to remember the path, as they would need to backtrack by themselves. Two groups were defined: the first group performed a spatial memory test at the goal destination and after backtracking; the second group performed the test only after backtracking. The mean spatial memory scores of the first group improved significantly after backtracking: from 49.8 to 60.8 %. The score of the second group was 62 %. No difference was found in performance between the first group and the second group. Backtracking alone significantly improves spatial memory of visited places. Surprisingly, repetition priming does not further enhance memorization of these places. This result may suggest that spatial reasoning causes significant cognitive load that thwarts further improvement of spatial memory of locations.

Keywords Wayfinding · Backtracking · Repetition priming · Spatial memory

✉ Michal Mukawa
stumam@i2r.a-star.edu.sg

Cheston Tan
cheston-tan@i2r.a-star.edu.sg

Joo-Hwee Lim
joohwee@i2r.a-star.edu.sg

Qianli Xu
qxu@i2r.a-star.edu.sg

Liyuan Li
lyli@i2r.a-star.edu.sg

[1] Institute for Infocomm Research, 1 Fusionopolis Way, Singapore 138632, Singapore

Introduction

Wayfinding in a novel indoor environment is a demanding task. Often, during this task, we will try to remember a navigational path, either to backtrack or to prepare ourselves for a next visit. Spatial memory plays a crucial role in this process, as it stores information about our environment.

Our vision is considered as the primary modality for spatial learning and memory of the environment (Shelton and Yamamoto 2009). During wayfinding, people prefer to use visual landmarks—memorable locations that help to orient the navigator within an environment—overother sources of information (Foo et al. 2007). Therefore, during exploration of a novel environment, we remember many landmarks and/or visual scenes encountered on the way, which may be used for wayfinding.

Those landmarks may be used for backtracking when we need to return to starting location; or for more efficient wayfinding when we will re-visit an environment. During backtracking, we set up expectations: we are anticipating to see some specific landmark (e.g., junction), either to confirm that we are on the right path or to perform wayfinding action (e.g., turn right) which corresponds to the perceived landmark (Spiers and Maguire 2008).

Published online: 28 July 2015

Our vision is essential for efficient exploration of a novel environment. However, we cannot process all perceived visual input; it is attention that allows us to optimize performance in a visual task. Attention affects which parts of a visual scene we will process; it impacts memories. Our attention is driven not only by currently perceived stimuli (bottom-up attention), but also by our memories (top-down attention).

Priming affects our top-down attention, which is driven not only by explicit, by also by implicit memories. What we have recently seen and attended our attention to, strongly influence how we will allocate our future attention (Maljkovic and Nakayama 1994). Therefore, attention affects which scenes will or will not be processes; it indirectly affects spatial memory of that scene.

Studies on repetition priming investigate effects of prior presentation of a stimulus on one's response to the same stimulus when it is presented at a later time. These priming pattern results from matching currently perceived stimuli with a memory representation of the previous trial (Huang et al. 2004). In addition, priming effects are visible even in people who do not remember the priming procedure; their implicit memory is affected (Warrington and Weiskrantz 1974).

As some visual scenes are more memorable than others, independent of the perceivers' memories of other biases (Isola et al. 2011), our study aims to investigate how repetition priming affects our spatial memory during backtracking in a novel environment. To the best of our knowledge, our experiment is the first work which investigates this question. Moreover, we check how backtracking alone improves memorization of encountered places.

Ultimately, understanding the effect of backtracking and repetition priming on spatial memory during wayfinding in a novel environment, may allow us to design better tools and training procedures in support for this demanding task.

Methods

Our experiment investigates whether repetition priming improves spatial memory of visited places during backtracking in a novel environment. It also checks whether backtracking alone improves memory of these places. The participants were asked to remember the taken path, as they would need to backtrack by themselves. A spatial memory retention test was carried out at different locations for two separate groups of the participants. The test checked which visited scenes were remembered after guided wayfinding and after backtracking.

Participants

Twenty adults (11 males and 9 females) were recruited. Ages ranged between 21 and 36 years old (mean age 26.2 years with standard deviation of 4 years). All participants had normal or corrected-to-normal vision. The participants had never visited the experimental environment (i.e., the institute building) before and had no prior knowledge of the office layout. The participants were randomly split into two groups: 1st Group: 6 males and 4 females; 2nd Group: 5 males and 5 females. The 1st Group underwent the spatial memory test twice: at goal location, and after backtracking to the starting location. The 2nd Group underwent the test only once: after backtracking to the starting location.

Instruments

The spatial memory retention test was carried out with the use of a tablet PC. For each shown image (i.e., stimulus), a participant needs to decide (by pressing either 'Yes' or 'No' button) whether he or she remember the presented scene. Each image is displayed for a maximum of 5 s. The distance between participant's eyes and the tablet screen varied: between 30 and 60 cm. For these distances, participants had seen the images at 45×18, and 24×9 degrees of visual angles, respectively.

Stimuli

Eighty images of indoor scenes were collected. Half of them were taken along the wayfinding path. These images are denoted as visited scenes. The other half were taken at different parts of the office environment, but at locations unseen from the wayfinding path. This subset is denoted as the unvisited scenes. Images of both visited and unvisited scenes were mixed together and presented to a participant in a random order.

Procedure

The experiment was carried out for individual subjects. After informed consent was obtained, a participant was lead to the starting point. A participant was instructed to remember the taken path, as he or she will need to backtrack without any support. Next, the participants were guided to the goal location. The spatial memory retention test, for the 1st Group, was carried out at the goal destination. Before the test, a participant was asked to fill up a few questionnaires that were not related to the study. It took around 3–5 min; therefore, we assume that the spatial memory retention test examine the participant's long-term spatial memory.

During the spatial memory retention test, 80 images of scenes were shown to the participants. For each presented scene, the participant needs to decide whether he or she had seen the scene along the traveled path. Based on the data

collected from the test, we got information about which scenes were remembered by a particular participant. After completing the spatial memory retention test, a participant was asked to backtrack to the starting location. During backtracking, no assistance was provided. At the starting location, all participants (1st and 2nd Group) were asked to fill up a few questionnaires and to conduct the spatial memory test.

Hypotheses

Our first hypothesis assumes that the participants should correctly recognize more encountered scenes after backtracking to the starting location, than after guided wayfinding (i.e., at the goal location). This hypothesis is based on current findings on human wayfinding. People use landmarks as decision points when choosing a correct route (Foo et al. 2007). Therefore, during backtracking their attention should be attracted by those scenes that contain valuable wayfinding information. Spatial memory of those scenes will be enhanced, and the recognition performance, during the memory test, should be higher.

Our second hypothesis assumes that the repetition priming—memory test performed at the goal location, that presents mixed visited and unvisited places in random order—will further improve spatial memory during backtracking. Our attention is driven not only by currently perceived stimuli, or given task, by also by our explicit and implicit memories; therefore, participants exposed to the test images—priming—should consciously or unconsciously look for the presented scenes during backtracking. Moreover, the participants may be curious how well they memorized visited scenes, as they became aware that we test their spatial memory. Some participants may also expect that they will be tested again, after backtracking to the starting location. In general, all the participants exposed to the priming should memorize more scenes after backtracking than the participants who do not conduct the memory test at the goal location.

Results

Here we present results collected from twenty participants (10 in the 1st Group and 10 in the 2nd Group). All participants successfully found the goal location during guided wayfinding. Also, all participants were able to backtrack by themselves to the starting location. Based on the data collected during the spatial memory test, we calculated a spatial memory score for each participant. The memory score is defined as the percentage of correct recognitions (i.e., true positive) of the visited scenes.

The effect of backtracking on spatial memory

To check how backtracking tasks enhance spatial memory of visited scenes, we compared the performance of the 1st Group at the goal location with the performance of the 2nd Group after backtracking (see Fig. 1). Average memory score of the 1st Group at the goal location was 49.8 % (SD = 8 %). Average memory score of the 2nd Group (i.e., only one test, after backtracking) was 62 % (SD = 15 %). Results show significant improvement [$t(18) = 2.13, p = 0.047$] of spatial memory after backtracking. Moreover, high correlation ($r_s = 0.71$) between the scenes memorized by the 1st and 2nd Group indicates that the participants memorized the same scenes during guided wayfinding and after backtracking.

The effect of repetition priming on spatial memory

1st Group of the participants was exposed to repetition priming—the spatial memory retention test at the goal location. After backtracking the same group was asked to repeat the memory test. This procedure was used to investigate if—and if yes, how strongly—repetition priming affects further enhancement of spatial memory during backtracking. Average memory score of the 1st Group improved significantly [$t(9) = -4.3$, $p = 0.002$] from 49.8 %, at goal location, to 60.8 %, after backtracking (see Fig. 1). Surprisingly, no significant difference [$t(18) = 0.18$, $p = 0.856$] was found in memory performance between the 1st Group (i.e., exposed to repetition priming) and the 2nd Group (i.e., tested only after backtracking). These results indicate that repetition priming does not enhance memorization of encountered locations. Finally,

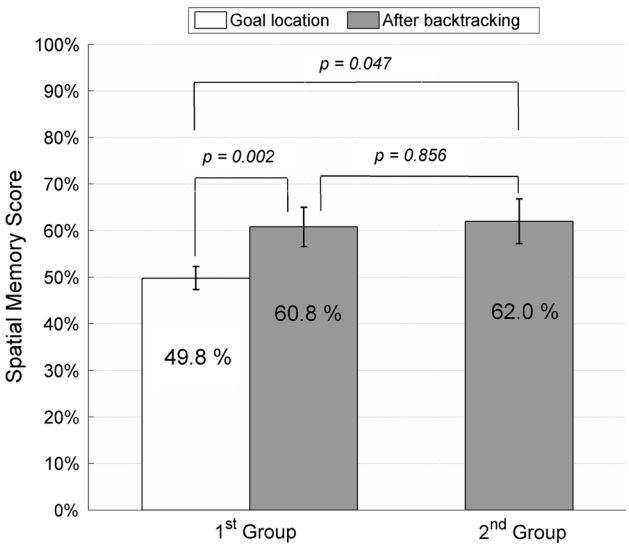

Fig. 1 Average spatial memory scores for the 1st Group (at goal location and after backtracking) and for the 2nd Group (only after backtracking) of the participants. *Error bars* show the standard error

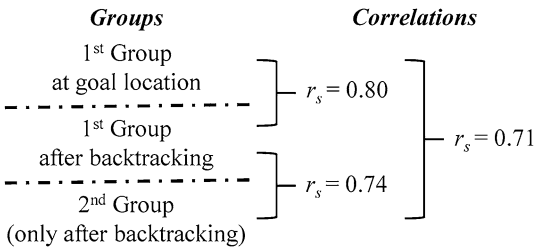

Fig. 2 Correlations between scenes memorized by the different groups of participants

high correlations, between scenes memorized by different groups, show that repetition priming does not affect selection of memorized scenes (see Fig. 2).

Discussion

Our experiment explores how backtracking and repetition priming affect spatial memory during wayfinding in a novel environment. Our hypotheses assumed that: (1) people should remember more visited scenes after backtracking to the starting location, compared to after guided wayfinding to the goal location; (2) repetition priming, in form of spatial memory test at goal location, should result in further enhancement of the spatial memory during backtracking.

The results confirm our first prediction. After backtracking, the participants correctly recognized more encountered scenes. Their attention is guided by a given task—backtrack to the starting location. They enhance spatial memory of encountered landmarks, which provide wayfinding information. Hence, their spatial memory of encountered scenes is strengthened. Moreover, during the search for landmarks, the participants probably memorize other, less significant but memorable, objects or visual scenes.

On the other hand, our second hypothesis is not supported by the results. Repetition priming does not further enhance memorization of these scenes. The participants exposed to priming memorized similar number of scenes as the participants who were not exposed to priming. This may be explained by the following reasons. Firstly, our attention is strongly guided by a given task and may be independently of priming (Leonard and Egeth 2008). Therefore, it is possible that participants focused only on the backtracking task and were unreceptive to the priming effect. Secondly, the cognitive load—associated with the backtracking task—might be too high, and thwarts further, conscious or unconscious, improvement of spatial memory.

High correlations between scenes memorized by different groups show that most of the participants remember the same visited places. This finding echoes the previous works on image memorability, which showed that people tend to remember the same images (Isola et al. 2011).

In the future, a simple modification of our experiment may bring some additional findings. We would like to investigate how backtracking and repetition priming affects people's spatial memory when they are not deliberately asked to remember a navigation path.

In general, our findings provide valuable insights on how backtracking and repetition priming affects spatial memory during wayfinding in a novel environment. These findings can be used to design better tools and training procedures to support this demanding task.

References

Foo P, Duchon A, Warren WH Jr, Tarr MJ (2007) Humans do not switch between path knowledge and landmarks when learning a new environment. Psychol Res 71(3):240–251

Huang L, Holcombe AO, Pashler H (2004) Repetition priming in visual search: episodic retrieval, not feature priming. Mem Cogn 32(1):12–20

Isola P, Xiao J, Torralba A, Oliva A (2011) What makes an image memorable?. In: Proceedings of the IEEE conference on computer vision and pattern recognition (CVPR)

Leonard CJ, Egeth HE (2008) Attentional guidance in singleton search: an examination of top-down, bottom-up, and intertrial factors. Vis Cogn 16(8):1078–1091

Maljkovic V, Nakayama K (1994) Priming of pop-out: I. Role of features. Mem Cogn 22(6):657–672

Shelton AL, Yamamoto N (2009) Visual memory, spatial representation, and navigation. In: Brockmole JR (ed) The visual world in memory. Psychology Press, Hove, pp 140–177

Spiers HJ, Maguire EA (2008) The dynamic nature of cognition during wayfinding. J Environ Psychol 28(3):232–249

Warrington EK, Weiskrantz L (1974) The effect of prior learning on subsequent retention in amnesic patients. Neuropsychologia 12(4):419–428