Mental Travel Primes Place Orientation in Spatial Recall*

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Abstract. The interplay of spatial long-term and working memories and the role of oriented and orientation-independent representations is an important but poorly understood issue in spatial cognition. Using a novel priming paradigm, we demonstrate that spatial working memory codes of a given location depend on previous tasks such as mental travels and are thus situated in behavioural context. In two experiments, 136 passersby were asked to sketch an image of a highly familiar city square either without or with prior metal travel, i.e. an imaginated walk along a route crossing the square. With prior mental travel participants drew the sketch more often in the orientation of the imagined route and less often in the orientation found without prior mental travel. This indicates that participants adjusted or selected information from long-term memory according to the situational context. We suggest that orientation priming plays a role in path planning and may facilitate way-finding afterwards. Possible mechanisms of orientation priming are discussed with respect to theories of orientation dependence in spatial memory.

Keywords: spatial cognition, priming, frame of reference, working memory, place recognition

1 Introduction

Finding one's way in large-scale spaces is a core cognitive function in humans and animals. In this task, spatial knowledge from long-term memory has to be activated and transferred to a working memory stage where planning, reasoning, and verbalisation takes place.

The relation of spatial long-term and working memories is often discussed in terms of the distinction of allocentric and egocentric representations. Allocentric spatial knowledge comprises the geometric shape of an environment [20] as

* Supported by the German Federal Ministry of Education and Research (BMBF) within the Tübingen Bernstein Center for Computational Neuroscience (Grant No 01GQ1002A)

well as object-to-object spatial relations either without a preferred orientation [18] or within an environmental reference frame [14, 13]. In contrast, egocentric systems code self-to-object relations as in perceptual representations or in view-dependent snapshots of the environment [18], [20]. Although the recall of spatial memories in general may involve allocentric codes, visual place recognition will mainly work with egocentric codes [5, 20]. Indeed, the anticipation of future viewpoints can facilitate later recognition of the previously anticipated views indicating egocentric involvement [1]. Subsuming allocentric representations (e.g., the structure of an object or a room) within an egocentric working memory stage may combine both types of spatial representations [12].
The information processing required to generate egocentric working memories from long-term memory depends on the assumed type of long-term place representation: If places are represented in a view-independent way [3], orientation has to emerge at the time of retrieval (transformation). If places are represented as a collection of views [8], the retrieval process will have to select (or interpolate) the appropriate view (selection). For path planning, Wiener & Mallot [21] hypothesised an egocentric working memory stage generated from the reference memory for each combination of ego position and local target locations along the path. Anticipating novel views within working memory may be involved in such processing [7].

The purpose of the present study was to test whether the orientation of a working memory representation built from spatial long-term memory can be primed by prior working memory activity such as path planning and mental travel. For this we used a novel priming paradigm and assessed the orientation specificity of retrieved spatial long-term knowledge as required for the production of place sketches. Our hypothesis predicts that the view orientation of these place sketches is primed by the direction of prior mental travel and thus by prior egocentric working memory representations. In contrast to most studies accessing memory representations of newly learned scenes, we tested highly-familiar long-term memory contents (i.e., a central square in the participants' home town) which is likely to have been encountered in many different orientations. Place sketches were analysed for view orientation. Sketches without prior mental travel (Experiment 1) worked as a baseline for sketches with prior mental travel (Experiment 2).

2 Experiment 1

2.1 Methods

Passersby at a University cafeteria were asked to sketch the "Holzmarkt", a well-known square in the medieval city centre of Tübingen (see Figure 1) within an 8×8 cm box provided on a DIN A6 (10.4×14.8 cm) sheet of paper. The University cafeteria was located approximately 2.5 km northwest of the Holzmarkt. About 30% of the people addressed agreed to participate. If participants asked in which perspective they should draw the square they were told to choose the perspective which they felt was most appropriate. After drawing, participants were asked to write down on the same sheet of paper their age, gender, place of residence (i.e., city district), and years of residency in Tübingen. Participation took approximately five minutes and was rewarded with candy.

From the 56 sketches obtained, six were excluded for incomplete data. Data from 27 women and 23 men (average age 22 years, SD = 2.2 years) were analyzed; on average, they had lived in or near Tübingen for 3.2 years (SD = 4.5 years). Three independent raters categorized the orientation of the sketches into north-up, south-up, east-up or west-up. They gave identical judgments for 49 of the 50 sketches (98%) corresponding to a very good chance corrected interrater-reliability of kappa = .96. Only the remaining 49 sketches were analyzed further.

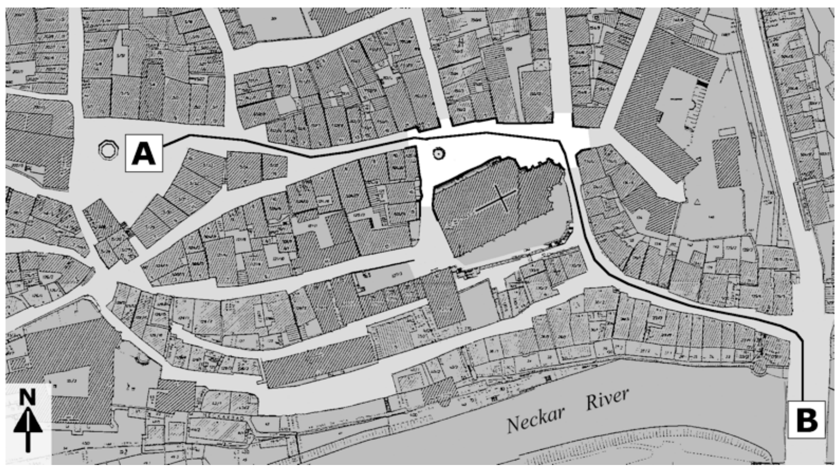

Fig. 1. City map of the Holzmarkt (white) and its surroundings including a prominent church bordering the square on the south side. Participants were asked to draw the Holzmarkt in both experiments. In Experiment 2 (orientation priming) participants were additionally asked to imagine walking a route (black line) either from A (Market) to B (Neckar Bridge, eastward route) or from B to A (westward route) before drawing. No map was shown to the participants.

2.2 Results

As shown in Figure 2 (left) participants sketched the square with a preferred orientation (χ^2 test against a uniform distribution: χ^2 (3, N = 49) = 78, $p < .001$). Eighty percent drew the sketches south-up in contrast to 25% expected by an equal distribution (one-tailed binomial test with $\pi = .25$ and N = 49: $p < .001$). Other orientations were drawn less often than 25% (north-up: 6.1%, $p = .001$; west-up: 10.2%, $p = .009$; east-up: 4.1%, $p < .001$). Individual differences (gender, age, time and place of residency) did not show any effects, neither here nor in the second experiment and thus are not further reported. Results are discussed in detail in conjunction with Experiment 2 below.

3 Experiment 2

3.1 Methods

General methods were the same as in Experiment 1, but before sketching, participants were asked to imagine walking a route across the Holzmarkt either in eastward or westward direction (Fig. 1). In the eastward condition, the written request *"Imagine to walk from the Market to the Neckar Bridge by crossing the Holzmarkt"* was handed to the participants. In the westward condition, Market and Neckar Bridge were exchanged. No participant of Experiment 2 participated also in Experiment 1. The experiment was run in multiple eastward/westward blocks, and participants were assigned to one of the two conditions in the sequence of recruitment.

All sketches of 81 participants could be analyzed (41 westwards, 40 eastwards, 42 women, 39 men). On average participants were 26 years old (SD = 9.5) and had lived in Tübingen for 6.7 years (SD = 9.1 years). All three raters agreed on orientation rating in all 81 sketches (interrater-reliability of kappa =1.0). All sketches were analysed further.

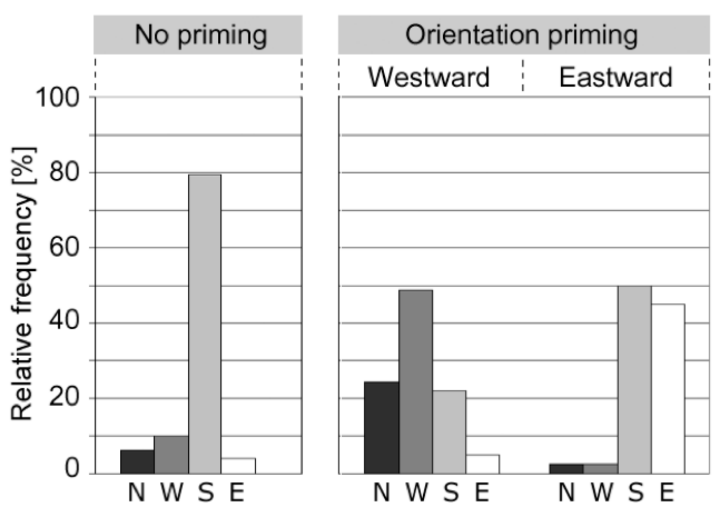

Fig. 2. Frequency of sketch orientations without (Experiment 1) or with orientation priming (Experiment 2). Sketch orientations: N = North-up, W = West-up, S = South-up, E = East-up.

3.2 Results

The distributions of sketch orientations differed between the two priming conditions (χ^2(3, N = 81) = 41.5, p < .001, Cramér's V = .72) and from Experiment 1 conducted without priming (see Figure 2; route westwards: χ^2(3, N = 90) = 31.5, p < .001, Cramér's V = .59; route eastwards: χ^2(3, N = 89) = 21.9, p < .001, Cramér's V = .50).

Participants were more likely to orient their sketches according to the primed direction. In the westwards priming condition, participants more often drew a sketch west-up (49% tested with a one-tailed binomial test against a probability of 10.2% as observed in Experiment 1, N = 41: p < .001) and north-up (24% tested against 6.1%, N = 41, p < .001). Less often they drew a sketch south-up (22% vs. 79.6%, N = 41, p < .001) which was the orientation mainly drawn without priming. We observed no differences in the frequency of sketching east-up (4.9% vs. 4.1%, N = 41, p = .505). In the eastwards priming condition, participants drew a sketch east-up more often than in the no-priming condition (45% vs. 4.1%, N = 40, p < .001). The south-up orientation was chosen less frequently (50% vs. 79.6%, N = 40, p < .001), but still was the most frequent one in this condition. No differences were observed for the north-up (2.5% vs. 6.1%, N = 40, p = .290) and west-up orientations (2.5% vs. 10.2%, N = 40, p = .075).

4 Discussion

In Experiment 1, participants chose to draw sketches of the Holzmarkt square mostly with the south-up orientation. As all participants were highly familiar with the area (i.e., had experienced the square many times from multiple perspectives), the physical structure of the square itself likely determined the orientation of its recall [14]. Orientation preference may be derived from the geometric layout (east-west) as well as from the salient landmark (church) at the south side, or the south-up geographical slant of the square (see [16]). If the place representation relies on one intrinsic orientation, our data suggest that this is the southward orientation, despite the fact that the long axis of the square is east-west. Alternatively, place representations could contain views with multiple orientations as has been suggested for place recognition [19] and route following [9]. In this case, we need to assume that one view (i.e., southwards) is preferred. The salient ancient church bordering the square on the south side or a particular shop may influence the retrieved orientation as well. Such an effect may depend on participant's special interests, which were not evaluated.

In Experiment 2, when primed by imagining a route crossing the square, participants' sketches were more often oriented along the direction of the imagined route and less often in the orientation preferred without priming. Thus, mentally walking a route, as might also be done during route planning [3], primed the orientation in which a location was recalled. That is to say, orientation priming changed the accessibility of the orientation of a place memory.

Standard priming procedures affect the accessibility of a stimulus by presenting semantically related, often co-occurring, or perceptually similar stimuli [15], by presenting an object located on a route before versus after the target object [6], or by presenting objects located close by versus further away from the target or within the same versus different spatial regions [10].

The orientation priming procedure used in the present experiment differs from other forms of spatial priming in that the primed item is not a particular place but the orientation in which this place is sketched or imagined. Also, priming is triggered not by the spatial, perceptual, or conceptual proximity of a stimulus, but by the (assumed) orientation of a working memory representation used during prior mental travel.

Spatial updating performance tested within the same space used for learning can be influenced by verbal instructions that persuade participants to be tested in the same space or in a different space as in the learning session [17]. Further, learning a layout and then update this layout by walking around the layout showed an advantage for judgments of relative direction from the updated orientation which is not the case when no updating happened at all. Nevertheless, subsequent maps of the spatial layout were always drawn from the learned perspective. Hence, no orientation priming affect occur in the drawings. In contrast to our experiment this approach tested short-term knowledge that was perceived from one perspective only. The present work examines spatial knowledge of a highly familiar city space that was experienced many times from various perspectives.

The orientation priming effect reported here affects the process of retrieving egocentric working memories of places from long-term memory (LTM). This process depends on the structure of long-term memory which may be view-dependent, aligned to an intrinsic reference direction, or independent of orientation. If LTM place representations are sets of views taken from various viewpoints (view-dependent memory [5, 20]), retrieval amounts to a selection process that picks one particular view to represent the place in working memory. In this case, orientation priming is the pre-activation of the view in LTM resulting in its subsequent selection. If, on the contrary, the environment is stored relative to an intrinsic reference direction and accessed more easily in that orientation [11, 14], imagining it in a different perspective requires a transformation such as a mental rotation into that perspective. In orientation priming, the transformed perspective might persist in working memory for subsequent recall. In orientation-independent memory [3, 18], the retrieval process may select a particular landmark object (rather than a specific view) and assumes the perspective under which this object appears when looking from the square. Orientation priming will then result from pre-activated object representations. In summary, different mechanisms will be responsible for orientation priming in the different long-term memory models: priming could result from the prior selection of views or landmark objects, or it might originate from the orientation of persisting working memory contents.

The distinction between the selection and transformation mechanisms for view-dependent long-term memory is akin to the distinction between representations for place recognition and representations for locating a goal relative to a given position, as suggested by Valiquette and McNamara [19]. It seems therefore possible that the two hypothesized mechanisms, selection and transformation, may even co-exist and support performance in different tasks.

Orientation priming affects the orientation of the recall of highly-familiar places. Our study substantiates that the retrieved orientation is not (only) dependent on the long-term memory content, but rather depends on the situational planning task. Further, our method of place sketches proves successful as appropriate tool to access the orientation of memory representations, which are well established in everyday long-term memory.

The present results were obtained within a mental travel task which primed recalled orientations. It will be an interesting opportunity for future research to test whether such an effect is also found in tasks involving physically walking along routes and whether this orientation priming will interfere with subsequent scene recognition tasks testing different perspectives (N, E, S, W).

Orientation priming is also in line with embodied cognition approaches which propose that representations, and in particular short-term representations, are based on sensorimotor and thus orientation-dependent representations [2, 22]. Neuronal correlates supporting such view-dependent representation of scenes can be found in the parahippocampal place area, which is activated during mental imagery of places and in mental navigation [4]. Recently, also a computational model of anticipating and storing views was proposed which is consistent with both neuronal processing as well as the present results [7].

One final question concerns the function of orientation priming. The purpose of processing information about a specific route will generally be to follow this route afterwards. Recognition of locations along the route should be facilitated, if the representation is aligned with the upcoming perspective [1]. In this sense off-line planning of routes might facilitate later online-cognition while walking the route. Orientation priming might thus help to effectively prepare for anticipated situations in way-finding tasks.

Acknowledgements. We would like to thank Sandra Holzer and participants of a spatial cognition course for help with data collection and analysis. Helpful comments on earlier versions of the text have been provided by Isabelle and Heinrich Bülthoff.

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