POSTER

Neural bases of route-survey processing in topographical memory

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Keywords Route knowledge • Survey knowledge • fMRI

Background

In the experimental psychology literature (Thorndyke and Hayes-Roth 1982; Ruddle et al. 1997), it is well admitted that recalling the direction to take along a familiar route or pointing to non-visible targets in large-scale environments are based on two different types of mental representations (route vs. survey), which are sustained by partially distinct neural networks. However, the neural bases of the route–survey distinction are poorly explored. Until now, the studies have been conducted in distinct environments (one for each type of representation), or in the same environment learned from different perspectives (from above or by navigation, see for instance, Shelton and Gabrieli 2002). In the present study, participants elaborated both route and survey knowledge of the same environment only from ground-level navigation, which is closer to natural situations.

Method

The present study involved 16 male young participants and used a complex town-like virtual environment presented by means of desktop (monitor) displays. During a pre-scanning learning phase, the participants were repeatedly shown a movie of a trip along a fixed route in a virtual environment, until they were able to reproduce the trip two times without errors (route knowledge). Then, they were requested to learn the relative position of some salient landmarks encountered along the route (survey knowledge) until their average pointing error was less than 20 degrees. During the scanning phase, the participants were presented with snapshots of the environment (see Fig. 1) and had to estimate either the direction to take to follow the previously learned route (Route direction condition) or the position of distant target landmarks (Survey direction condition). In a Control condition, they had to indicate the position on the screen of a non-target building located in an empty environment. Imaging was performed using a 3T whole-body imager MEDSPEC 30/80 AVANCE (Bruker). In a first step, a general linear fixed-effect model was applied for each participant to the time course of the functional signal at each voxel. In the second step, a random effect analysis was performed on the group data.
In the Route condition, the participants were shown a snapshot of the environment, from which they had to indicate the direction to take at the next decision point in order to follow the route previously learned. On the top of the screen, a scrambled image of the same size and luminance of the images used in all conditions was presented. On the bottom of the screen, a scheme reminding the available responses (turn left, go ahead, turn right) and the corresponding keys to press was shown. Following their response, the participants were presented for 250 ms with an empty grey screen and then were dropped at a different location in the environment for a next trial. In the Survey condition, the participants were presented with a snapshot of the environment, from which they had to estimate the position of a target landmark in relation to their current location in the environment. On the top of the screen, an image of the

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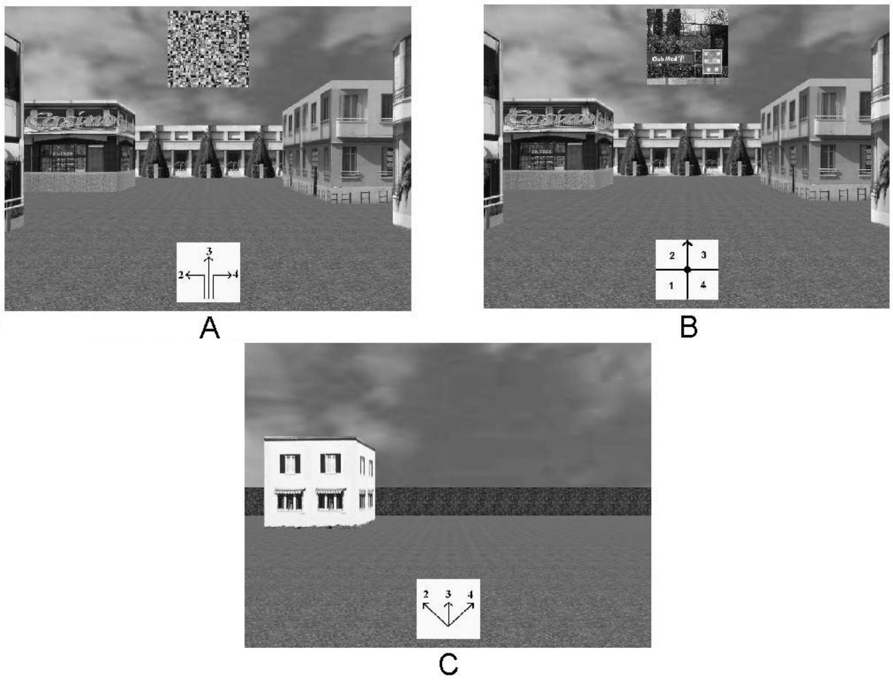

Fig. 1 Sample of stimuli presented during scanning: route condition (a), survey condition (b) and control condition (c). In the route condition, the participants were shown a snapshot of the environment, from which they had to indicate the direction to take at the next decision point in order to follow the route previously learned. On the top of the screen a scrambled image of the same size and luminance of the images used in all conditions was presented. On the bottom of the screen a scheme reminding the available responses (turn left, go ahead, turn right) and the corresponding keys to press was shown. Following their response, the participants were presented for 250 ms with an empty gray screen and then were dropped at a different location in the environment for a next trial. In the survey condition, the participants were presented with a snapshot of the environment, from which they had to estimate the position of a target landmark in relation to their current location in the environment. On the top of the screen an image of the front of the target building was presented. On the bottom of the screen a scheme reminding the available responses (in front to the left, in front to the right, behind) and the corresponding keys to press was shown. Following the response and after 250 ms of blank gray screen, the participants were immediately dropped at a different location in the environment for a next trial. It is important to note that the target landmark was always the same within each survey memory epoch (only the test location varied). In the control condition, the participants were presented with a snapshot of an empty environment. A single building (belonging to the practice environment) was presented on the screen. The participants had to indicate the position of this building with respect to their body midline. On the bottom of the image a scheme reminding the available responses (left, center, right) and the corresponding keys to press was shown. Following the response and after 250 ms of blank gray screen, the building was re-positioned in front of the participant for a next trial

reminding the available responses (turn left, go ahead, turn right) and the corresponding keys to press was shown. Following their response, the participants were presented for 250 ms with an empty grey screen and then were dropped at a different location in the environment for a next trial. In the Survey condition, the participants were presented with a snapshot of the environment, from which they had to estimate the position of a target landmark in relation to their current location in the environment. On the top of the screen, an image of the front of the target building was presented. On the bottom of the screen, a scheme reminding the available responses (in front to the left, in front to the right, behind) and the corresponding keys to press was shown. Following the response and after 250 ms of blank grey screen, the participants were immediately dropped at a different location in the environment for a next trial. It is important to note that the target landmark was always the same within each survey memory epoch (only the test location varied). In the Control condition, the participants were presented with a snapshot of an empty environment. A single building (belonging to the practice environment) was presented on the screen. The participants had to indicate the position of this building with respect to their body midline. On the bottom of the image, a scheme reminding the available responses (left, center, right) and the corresponding keys to press was shown. Following the response and after 250 ms of blank grey screen, the building was re-positioned in front of the participant for a next trial.

Results

Brain functional data (random effect analyses, corrected threshold $P < 0.05$) revealed some areas of activation shared by both Route and Survey conditions when compared with the Control condition (right Hippocampus, bilateral Parahippocampal Gyrus, Lyngual Gyrus, Posterior Cingulate Cortex and Parietal Lobe) and

some areas specifically activated when the Route direction Condition was compared to the Survey direction Condition (left Parahippocampal Gyrus, right Lingual Gyrus and Parietal Lobe, and bilateral Cuneus).
Between-subject performance-dependent comparisons revealed that good route performers presented activation of a specific network of cortical areas as the inferior Parietal Lobe and the superior Temporal Gyrus. By contrast, good survey performers were characterized by activation of the left Hippocampus.

Conclusions

These data revealed that route and survey processing acquired from ground-level navigation involved in common a large network of areas, including the right and left Hippocampus, while survey memory recruited a subset of areas recruited by route memory. These data are partially consistent with those gathered in studies which have been concerned with the neural bases of route versus survey knowledge either acquired from different perspectives (Mellet et al. 2000; Shelton and Gabrieli 2002) or in different environments (Hartley et al. 2003). They suggest that the distinction between the neural bases of Route versus Survey knowledge should be less marked as mentioned in classical studies if a single environment is used.

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