Way-finding improves visual memory for built environments

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Abstract. We describe an experiment that was designed to explore differences between active and passive travelers in a way-finding task. In this study, we examined the effect of active travel mode on spatial and visual memory for a built environment. After completing a way finding task in a university campus, we tested participant's memory for the test route using sketch map, mirror-image discrimination, and scene recognition tests. In addition, we tracked participant's eye movements during the scene recognition test. Results were consistent with the hypothesis that active travelers had enhanced memory for the built environment. Our data also provide some evidence for qualitative differences between active and passive travelers in the visual cues they used to recognize scenes. Based on our findings, we suggest that travel mode is an important consideration when designing built environments.

Keywords: cognitive map, eye-tracking, spatial ability, travel mode, urban design, visual memory, way-finding.

1 Introduction

Way-finding involves interaction between the traveler and the environment, and a variety of cognitive processes are engaged by this task. For example, successful navigation requires the generation of accurate cognitive maps which requires memorizing, recognizing, and decoding spatial information and location attributes, as well as forming an action chain of spatial knowledge [1]. Spatial ability is a combination of different sub-skills including the ability to read maps and understand geometry [2].

Despite the focus on the process of cognitive mapping in previous navigation research [3, 4], we propose that travel mode might also affect visual memory for the built environment. Therefore, in this study we aim to investigate the extent to which travel mode affects both memory representations of spatial relations, and also the accuracy of scene recognition.

We hypothesized that active travelers would have more accurate memory for spatial layout of study routes than passive travelers (i.e. cognitive maps), but they would also have better memory for scenes encountered during the way-finding process.

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2 Experiment

2.1 Participants

One-hundred-and-eight participants (52 Females) were randomly assigned to active or passive traveler groups (54 participants in each group). Participants' ages ranged from 17 years to 58 years (M=23.9; SD = 7.07).

2.2 Procedure and tasks

Participants first completed the *way-finding task*. They were given a map showing the predetermined route and three 'key landmarks' to answer the questions relating to each landmark. Passive participants were asked to follow the experimenter through the test route, whereas the active groups led the experimenter through the test route. Both groups were instructed to pay attention to their surroundings.

After the test route had been completed, participants filled a *Spatial Ability Questionnaire* and *Sketch Map* test. In the questionnaire, participants made subjective judgments of their own spatial ability, their level of familiarity with the campus, and spatial layout of the campus. In the sketch map test, participants were given a partially completed map of campus containing only start point of the test route, and were instructed to draw the test route and locate the key landmarks as accurately as possible.

Next, participants were presented with scenes containing main buildings and landmarks on and off the study route for completing the *Mirror-image Discrimination* test (MD), and *Scene Recognition* test (SR). MD was designed to test the memory for orientation of scenes – participants were shown images of scenes and mirror-reversed versions of these side-by-side on a computer screen. They had to select the correct orientation of the images. We predicted that orientation of scenes would be encoded in memory more accurately by participants in the active traveler group.

Finally, for the *scene recognition test*, participants were shown fifty-four images (half on-route, half off-route). They had to indicate whether the scene was encountered on the route or not. In addition to measuring the accuracy, we also recorded their eye-movements whilst they completed this task by a static eye-tracker (Tobii TX300).

3 Results

3.1 Scene Recognition Test

Recognition memory performance. Active travelers were more accurate in this test (Mean correct = 85.5; SD =11.1) than passive travelers (M = 81.7; SD =15.2). An independent sample *t*-test confirmed that this difference was statistically significant, $t(96) = 2.00$, $p < 0.05$.

Eye tracking analysis. We analysed eye movements by defining Areas of Interest (AOIs) for each of the images in the *Scene Recognition Test* (see Figure 1). The two dependent variables were total fixation count per AOI, and mean gaze duration per AOI (Table 1). Total fixation count measures the number of fixations to an AOI; and mean gaze duration is the length of time for one visit in an AOI from entry to exit [5]. Two separate 2x3 mixed ANOVAs were run for each of the dependent variables with factors Travel Mode (active/ passive) and AOIs (first floor, upper floors, and non-buildings). AOIs were defined based on the assumption that people would primarily use landmark-based strategy rather than layout geometry-matching strategies [8].

We were only interested in interaction between Travel Mode and AOIs. This interaction was non-significant for Fixation Count $F_{2,\,212} = 1.66$, $p > 0.05$, $\eta 2 = .01$. However, for Gaze Duration the interaction was significant, $F_{2,\,212} = 3.22$, $p < 0.05$, $\eta 2 = .03$. This interaction indicates that travel mode affects visual cues encoded in memory by participants during way-finding.

To investigate the interaction effect in gaze duration data, we carried out planned comparison t-tests between active and passive groups for each AOI. This test revealed greater reliance on First Floors among passive travelers compared with active travellers, $t\ (106) = -2.71$, $p < 0.05$ (not in upper floors, $t\ (106) = 0.34$, $p > 0.05$, and non-building, $t\ (106) = 0.12$, $p > 0.05$).

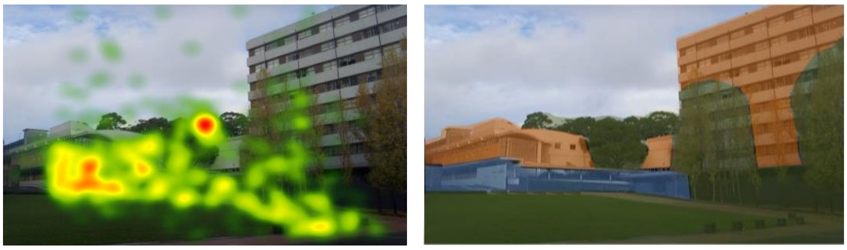

Fig. 1. Examples of heatmaps and defined AOIs from aggregate data of both groups of active and passive travelers; Blue: First Floor, Orange: Upper Floors, Green: Non-buildings (Left image shows heat maps; Right image shows the AOIs).

Table 1. Mean data for eye tracking (Gaze duration in seconds, standard deviation in parenthesis)

	Fixation Count			**Mean Gaze Duration**		
	First Floor	Upper Floors	Non-building	First Floor	Upper Floors	Non-building
Active	6.17 (1.2)	5.36 (1.12)	5.29 (1.18)	0.88 (0.17)	0.63 (0.16)	0.74 (0.20)
Passive	6.41 (1.16)	5.09 (0.94)	5.31 (0.83)	0.97 (0.18)	0.62 (0.16)	0.74 (0.18)

3.2 Mirror-image Discrimination Test

We analyzed accuracy data on the *Mirror Discrimination Test* with 2x3 repeated measure ANOVA with factors Travel Mode (active/ passive) and Image Type (on-route campus, off-route campus, off campus). There was a significant main effect of travel mode, $F_{1,\,103} = 4.15$, $p < 0.05$, $\eta 2 = .040$, and of image type, $F_{1.9,198} = 42.63$, $p < 0.05$, $\eta 2 = .040$. However, the interaction between factors was not statistically significant, $F_{1.9,\,198} = 0.48$, $p > 0.05$, $\eta 2 = .005$. This result shows that the ability to correctly identify the orientation of visual scenes was enhanced for the active travelers, but that this benefit was not specific to images from the test route. It is not possible based on the data from this study to determine whether this effect was caused by the experimental manipulation used in this study, but we intend to follow this up in future research.

Table 2. Mean percentage of correct responses in the Mirror-image Discrimination test (standard deviation in parenthesis)

Travel Mode	On Route Campus	Off Route campus	Off Campus	Overall
Active	86.5 (11.3)	74.9 (15.0)	71.3 (18.8)	77.6 (16.6)
Passive	81.4 (12.7)	70.7 (13.2)	68.5 (16.1)	73.5 (15.1)

3.3 Sketch Maps

Sketch maps were geo-referenced and analyzed separately in ArcMap 10. The sketch maps were analyzed according to six factors, namely: route dislocation, landmark and building dislocation, open space dislocation, number of landmarks, number of spaces, and number of details. An independent t-test reveals that there was a statistically significant difference between groups in open space dislocation, with passive travelers were scoring higher than active travelers, -41.6 (95% CI, 80 to 3), $t(91) = -2.1$, $p < 0.05$. All other comparisons were non-significant. Table 3 presents the mean and standard deviation for each six items.

Table 3. Mean of dislocations from the reality in sketch maps (standard deviations in parenthesis)

	Route dislocation (m^2)	Landmark & building dislocation (m^2)	Open space dislocation (m^2)	Number of landmarks	Number of spaces	Number of details
Active	8384 (3276)	116 (54.8)	130 (75)	2.0 (1.4)	3.4 (1.5)	5.7 (2.9)
Passive	9373 (3300)	133 (59.1)	172 (109)	1.4 (1.1)	3.2 (1.6)	5.7 (3.9)

3.4 Spatial Ability Questionnaire

SAQ scales were derived from Santa Barbara Sense of Direction Scale [6], namely: navigating to a place, reading maps, orienting one's location using cardinal directions, and estimating distance. The average score across scales was used as the estimated participants' spatial ability. Table 4 shows Spearman's r values for spatial ability as measured through the questionnaire, against each of the tests reported here. From these data we conclude that accuracy on the MD task provides a fairly good measure of people's spatial ability. The negative relationship between spatial ability and *dislocation of landmarks and buildings* shows that participants with higher SAQ scores provided more accurate estimates of landmark location in the Sketch Map test.

Table 4. Correlations between spatial ability of participants and their performance in each test (*p*-value in parenthesis) * = p<0.05

Correlations	Mirror-image Discrimination			Sketch Maps		
	On Route	Off Route	Off Campus	route dislocation	landmark & building dislocation	Open space dislocation
SAQ score	0.268*	0.127	0.192*	-0.121	-0.287*	-0.031

4 Discussion and conclusion

Our results suggest that active travelers had better memory for the built environment than passive travellers. This memory benefit manifested in two ways. First, in line with previous studies [3, 4, 7], active travelers recalled spatial layout of the environment more accurately than passive travelers, by producing more accurate sketch maps. Second, active participants were better able to recognise visual scenes from the study route than passive travellers. This is a novel finding that has important implications, suggesting that episodic visual memory plays a crucial role in way-finding. In a practical sense, it suggests that accuracy of navigation in cities could be enhanced by promoting the development of eye-catching and memorable buildings and other structures, monuments, and landscapes.

Our data also provide evidence that memory for built environments differs qualitatively as a function of travel mode. Specifically, eye tracking analysis showed that passive travelers looked more at first floor of buildings, perhaps suggesting that they were more concerned with visual details immediately in front of them during the way-finding task. In future research it will be important to reveal which characteristics of the visual environment are most beneficial to the process of way-finding.

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