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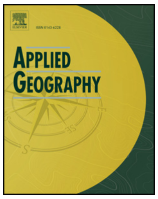

Effects of active and passive exploration of the built environment on memory during wayfinding

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ABSTRACT

Previous research shows that travel type influences cognitive mapping processes. However, little is known about the effect of active versus passive exploration of the built environment on visual processing. This paper aims to investigate the differences between active and passive travellers in terms of their recognition memory for details of the visual environment. Participants were randomly assigned to either active or passive travel conditions. Participants in the active group navigated a pre-defined route on a university campus by walking, and passive participants followed an experimenter around the same route. We examined the effect of active travel by measuring performance on spatial and visual memory tasks and by tracking participants' eye movements during a scene recognition task. Active travellers had better recognition of scenes encountered during way finding and were better able to discriminate the veridical orientation of these scenes from mirror-reversed copies. The results indicate that active travellers had enhanced visual memory for the built environment. Results are discussed in the context of visual memory and urban design and place-making for legible cities.

1. Introduction

Way-finding is a decision-making process which involves cognitive processes including memorizing, recognizing, and decoding spatial information and location attributes (Kitchen, 1996). The internal representation of perceived environmental features and spatial relations among them is known as a cognitive map (Golledge, 1999). Thus, wayfinding, a cognitive process (Golledge, 1999), can be defined as spatial behaviour (Julian, 2010) that involves the ability to learn a route and retrace it from memory (Blades, Lippa, Golledge, Jacobsen, & Kitchin, 2002) to move from an origin to a destination while, maintaining orientation in and around objects, people, and spaces. It is the process of collecting information from our built environment to know where we are, where we want to go and how to get there (Woyciechowicz & Shliselberg, 2005).

Previous research has conceptualized wayfinding as a process that requires people to either mentally represent the world through a spatial description (known as a 'cognitive map') or to use way-finding aids, which are the external representations of the environment such as maps or signage (He, Ishikawa, & Takemiya, 2014). However, far less research has examined the contribution of episodic memory for visual details in the environment to this process. We propose that the process of encoding, storing and recognizing visual details of the environment is a critical part of the wayfinding process.

We tested the contribution of visual memory to wayfinding by conducting an experiment where participants were navigated in a familiar and partially familiar environment. Critically, we tested whether memory for scenes was enhanced in people that actively navigate their environment compared to passive travellers. This is practically important, because understanding the processes involved in encoding scenes during navigation can inform development of navigational aids. Further, as we argue below, it is important to understand the interaction between visual memory and spatial representations that drive wayfinding processes.

2. Literature review and research questions

In either new or unfamiliar places people are looking for cues to find their way around. These cues are mostly known as landmarks; we use the term "visual cues" in this paper. Also, depending on the environment people are travelling in and the type of travel they are traversing, utilizing landmarks could vary. Previous studies on landmarks are

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numerous and varied from geocentric cues (e.g. Boles & Lohmann, 2003), to more visual cues (e.g. Collett & Collett, 2000), and map following (e.g. Ruddle, Payne, & Jones, 1999).

Wayfinding studies and landmarks make essential contributions to the built environment and particularly urban design studies about legibility and visual cues. A better design of the built environment – in terms of legibility-is possible through recognizing and applying the informative visual cues for wayfinders (Afrooz, 2016). This, in turn, can lead to connectivity in designing public places and spaces (i.e. connecting urban places physically and spatially to enhance the urban wayfinding system). Landmarks are also important features in the built environment because they organize other spatial information into a layout, similar to nodes (Samany, Delavar, Saeedi, & Aghataher, 2008). In addition, landmarks make the built environment legible by providing directional information to the user (Winter, Raubal, & Nothegger, 2005).

Although, the importance of landmarks for successful way-finding has been studied extensively (see Dalton & Bafna, 2003; Lynch, 1960; Sorrows & Hirtle, 1999), what makes a landmark last longer in a wayfinder's mind has not been sufficiently examined so far.

Aginsky, Harris, Rensink, & Beusmans (1997) believed that, in line with Appleyard (1969) and Cohen & Schuepfer (1980), people only retain information from along the route and particularly at decision points. In other words, objects closer to the decision points, such as intersections or near turns, are more likely to be remembered as landmarks (Aginsky et al., 1997).

Many scholars have studied the differences between "active exploration" and "passive exposure" of the built environment with regard to cognitive map (e.g. Appleyard, 1970; Chorus and Timmermans, 2010; Mondschein, Blumenberg, & Taylor, 2010) In this paper, we differentiate between an active and a passive traveller and a person who is using active or passive modes of travel. An example for active modes of travel are cycling and driving a car and passive modes include busses, taxis and driverless vehicles, which involves the person being taken to a place (Hart, 1981; Mondschein et al., 2010). An active traveller, in this paper, is defined as a person who is actively involved in a way-finding process whereas a passive traveller is not directly involved in this process. An example of an active traveller is a traveller who is cycling or driving to a destination. An example of a passive traveller is a passenger in a taxi who is guided to a destination. (Afrooz, White, & Neuman, 2014a).

Previous research has shown superior spatial memory representations in active travellers compared to passive travellers. Mondschein et al. (2010) found that differences in modal travel experiences were associated with differences in the content and construction of individual's cognitive map, with passive modes of transport leading to travellers having representations that were less complete than active travellers. Similarly, Appleyard (1970) found that among those who traveled by bus, eighty percent were unable to present a coherent map of the urban road system while all the maps drawn by car travellers were coherent. This indicates that drivers (active travellers) developed better survey knowledge than the passengers (passive travellers) (Chrastil & Warren, 2012). The results from the study of Chorus & Timmermans (2010) supported studies of Mondschein et al. (2010) and Appleyard (1970), showing that using active modes increases a person's perception of the quality of their construction of urban space and has a positive effect on revealed mental map quality.

So far, the differences between different exploration types of the built environment (i.e. active or passive exploration) have been mainly measured for cognitive maps. Yet the influence of a major value of visual memory has been neglected in both way-finding studies and most other urban-related studies. Visual (episodic) memory is the memory of events and objects (e.g. where you left your key) which is mostly in the form on an image (Conway, 2009). One exception to this is a study by Sauzeon et al. (2012), who assessed memory for objects encountered in a Virtual Reality (VR) environment. They examined the effect of active vs passive navigation mode and found better recognition performance for active relative to passive travellers. In a follow up study, Sauzeon, N'Kaoua, Pala, Taillade, & Guitton (2016) investigated the age effect on episodic memory, again concluding that active navigation increased recognition performance.

Building on this work, we assessed the effects of active vs passive navigation on visual memory of a university campus. Specifically, we test whether travel type affects the way that the built environment is encoded in visual memory. We assess this by testing participant's memory for the environment after performing a navigation task. In addition, we carry out exploratory analysis of participants eye movement strategies to examine the nature of memory representations encoded during the wayfinding process. Eye tracking has been used in previous work to identify the visual cues that enable recognition (see Johansson, Holsanova, Dewhurst, & Holmqvist, 2012; Johansson & Johansson, 2014), and we hoped it would also provide insight into the visual information supporting scene recognition in the current study.

This paper expands on results reported in a previous paper (Afrooz, White, & Neuman, 2014b)[2] regarding the impact of travel type on visual memory. Here we provide a description of the results related to visual memory of this large-scale study.

3. Experiment

In this study we asked participants to navigate through a predefined route on the university campus of UNSW Sydney, either by following the experimenter (passive navigation), or by leading them (active navigation). The university campus is selected rather than a virtual environment to investigate wayfinding in a real environment and to ensure direct response of any findings to the real physical environment (Emo et al., 2014). A university campus rather than a city is selected to control confounding variables and avoid factors affecting the data collection process such as crowds and noise.

Afterwards, we tested participants memory for scenes encountered on this route (scene recognition test) and for the left-right orientation of these scenes (mirror image discrimination) and their recollection of the study route (sketch maps). In addition, we measured their eye-movements when performing the scene recognition task.

3.1. Participants

One-hundred-and-eight participants (52 Females) were randomly assigned to active or passive traveller groups; 54 participants in each group (Table 1). Selection of all participants was based on their level of familiarity with the environment; so the participants were either familiar or partially familiar with the campus (i.e. more than 6 months studying at campus). Participants' ages ranged from 17 years to 58 years (M = 23.9; SD = 7.07).

3.2. Procedure and tasks

Participants first completed the way-finding task. Participants in both groups were given a map of UNSW Campus showing the predetermined route and three "key landmarks" to answer the questions relating to each landmark. The "key landmarks" were labelled as points 1, 2, and 3 on the map (Fig. 1). The route has been selected through a pilot study using a mobile eye tracker (Tobii glasses, monocular 30 Hz) to identify scenes that were viewed when led through the route. The final selection of stimuli was chosen to be salient scenes that were distributed throughout the route.

The route through campus is shown in Fig. 1 in red. Two separate experimental conditions were assigned for each group of active and

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[2] The partial results of the study (Afrooz et al., 2014b) were reported in the ET4S conference published in Vienna, Austria, September 2014.

Table 1
Number of participants for each task.

Task	Participants	Group
Way-finding task	n = 108	n = 54 (active) n = 54 (passive)
SAQ	n = 108	n = 54 (active) n = 54 (passive)
Sketch map	n = 108	n = 54 (active) n = 54 (passive)
Mirror-image Discrimination	n = 108	n = 54 (active) n = 54 (passive)
Scene Recognition	n = 108	n = 54 (active) n = 54 (passive)

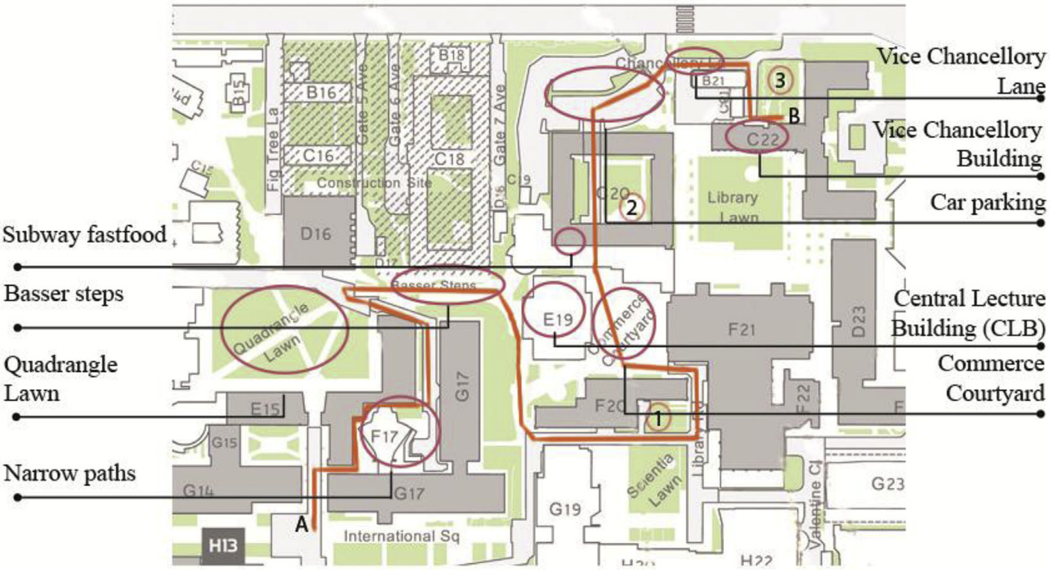


Fig. 1. Case Study (UNSW campus); the red line represents the Test Route, 3 digits represent the Key Landmarks. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

passive participants. Participants were tested individually. They either followed the experimenter through the study route (*passive* group) or were asked to find their own way through the study route *(active* group). Both active and passive traveller groups followed the same route. The researcher followed the active traveller participant to ensure that s/he was traversing the same route whereas in the passive group, the participant followed the researcher. The active travellers were using the map while the passive travellers were shown the map once and were advised to follow the researcher and only pay attention to the surroundings.

After the test route had been completed, participants then completed a *Spatial Ability Questionnaire (SAQ)*, and *sketch map* test. In the SAQ, participants made subjective judgments of their own spatial ability, their level of familiarity with the campus, and spatial layout of the campus. The route has been divided into three sections (i.e. from point A to 1, 1 to 2, and 2 to B) based on decision subclasses which were required to be taken (see Aginsky et al., 1997). In the sketch map test, participants were given a partially completed map of campus containing the start point of the test route and the UNSW main Library. They were instructed to draw the test route and locate any 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, and *scene recognition* test. Conway's (2009) experimental research suggested that many of the episodic memories of a day could be accessed again using photographs. Accordingly, site images were utilised in this study in the design of mirror-image discrimination and scene recognition tests. Mirror-image discrimination 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 and had to decide which image showed the correct orientation of the scene. Images consisted of total eighty-one images, 27 of which were scenes encountered on the route, 27 were similar scenes of the university campus that had not been encountered and 27 were scenes from other locations in Sydney (n = 27 for each category of: on route campus, off route campus, and off campus).

For the scene recognition test, participants were shown fifty-four images, half of which were scenes encountered on the route, and half were similar scenes of the university campus that had not been encountered on the route. Participants 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).

4. Results and discussion

4.1. Scene recognition test

4.1.1. Recognition memory performance

Active travellers were more accurate in this test (Mean correct = 85.5; SD = 11.1) than passive travellers (M = 81.7; SD = 15.2). An independent sample *t*-test confirmed that this difference was statistically significant (t (96) = 2.00, p = 0.04; chance is 50%). The result provided evidence that active travellers had better memory for the built environment than passive travellers. This finding addresses our key research question in regard to visual memory which is in line with the recent study by Sauzeon et al. (2016) examining the neuropsychological aspects of age effects on navigation. The finding that way-finding is affected by visual memory is also consistent with Chrastil & Warren (2012). Thus, our data provides evidence that memory for built environments differs qualitatively as a function of travel type.

4.1.2. Eye tracking analysis

We analyzed eye movements by defining Areas of Interest (AOIs) for each of the images in the scene recognition test (see Fig. 2). Three categories of AOIs were defined including: first floor, upper floors, and

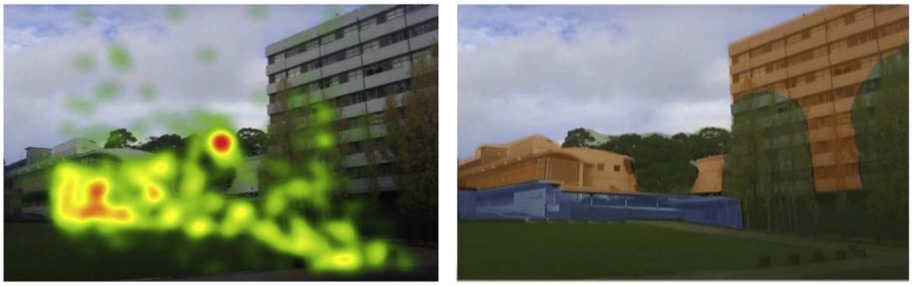


Fig. 2. Examples of heatmaps and defined AOIs from aggregate data of both groups of active and passive travellers; Blue: First Floor, Orange: Upper Floors, Green: Non-buildings (Left image shows heat maps; Right image shows the AOIs). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 2

Mean data for eye tracking (Gaze duration in seconds).

Group	Fixation Count			Mean Gaze Duration		
	First Floor	Upper Floors	Non-building	First Floor	Upper Floors	Non-building
Active	6.17 (1.2)[a]	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)

[a] Values in parentheses are standard deviations.

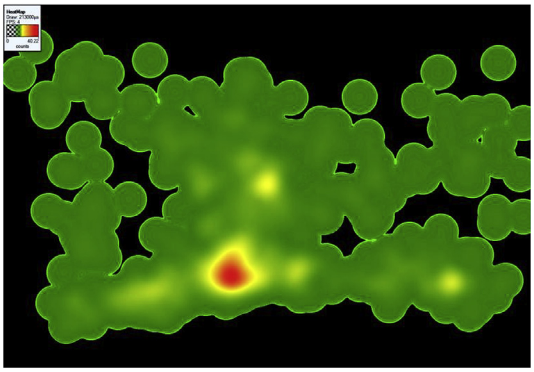


Fig. 3. Examples of a heatmap layer of active travellers group on selected stimuli (Image R1).

non-buildings. AOIs covered the visual cues since the informative visual cues tended to be found. Further, the manmade and natural visual features (i.e. buildings and landscape features) were differentiated.

The two dependent variables were total fixation count per AOI and mean gaze duration per AOI (Table 2). 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 (Holmqvist et al., 2011). Two separate 2 × 3 mixed ANOVAs were run for each of the dependent variables with factors *travel type* (active/passive) and *AOIs* (first floor, upper floors, and non-buildings). The aggregated heatmaps were generated automatically in TobiiStudio. We were only interested in interaction between travel type and AOIs. This interaction was non-significant for fixation count (F2, 212 = 1.66, p = 0.19, η2 = 0.01). However, for gaze duration the interaction was significant (F2, 212 = 3.22, p = 0.02, η2 = 0.03). This interaction indicates the influence of visual memory during way-finding for each group of active and passive travellers. To investigate the nature of this interaction, 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 travellers compared with active travellers (t (106) = −2.71, p = 0.008 (not in upper floors, t(106) = 0.34, p = 0.731) and non-building AOIs (t (106) = 0.12, p = 0.90). Therefore, the comparison of eye movements between groups suggests that active and passive travellers looked at similar places but for different durations. Specifically, eye-tracking analysis showed that passive travellers looked more at the first floor of buildings, perhaps suggesting that they were more concerned with visual details immediately in front of them during the way-finding task.

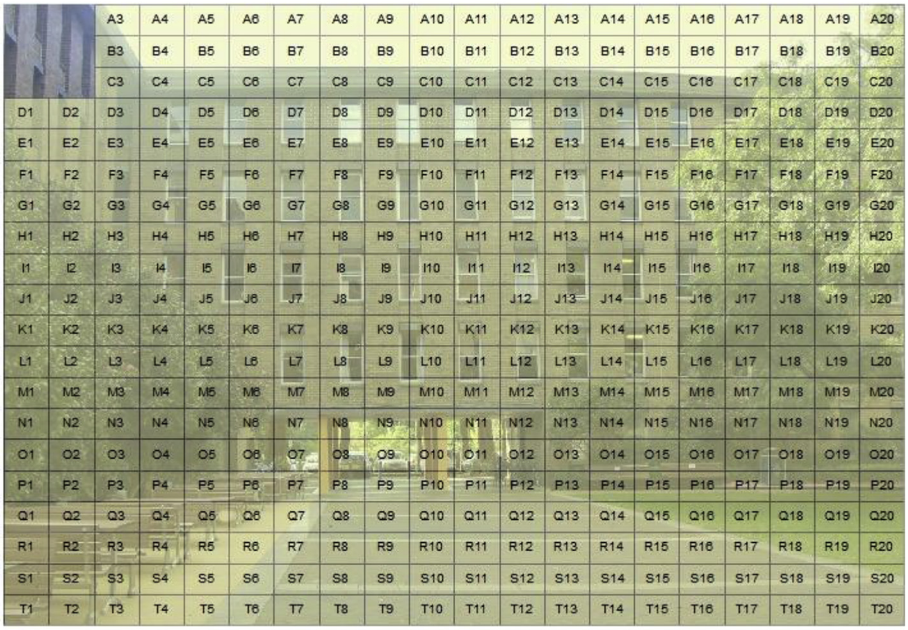
Next, we investigated any differences in the eye movement patterns between the groups (i.e. active and passive travellers). The layers of heatmaps were extracted from TobiiStudio (Fig. 3) for each group separately and were then imported into ArcMap 10.2. The heatmap layers were showing the count and not the absolute duration of eye movements because count shows the semantic importance (Holmqvist et al., 2011) which is what this analysis looks for. A grid index feature was defined for each heatmap layer separately. The grids were adapted to the scale of buildings and were defined in a way to indicate nearly 1meter height of the targeted building in the building plane perspective (Fig. 4). Next zonal statistics (spatial analyst tools) were utilised to generate a raster file based on the mean of the 3 bands of each heatmap layer (Figs. 5 and 6). An additional table of zonal statistics was also generated for each stimulus which showed the mean and other descriptive statistics. This was saved in an Excel Spreadsheet where the mean of each stimulus among active and passive travellers was compared.

The Pearson correlation was used to compare the mean RGB value for each stimulus among each group of active and passive travellers. The result is summarized in Table 3. It shows the correlation between travel type and eye movement patterns of participants. For example, for Image R1, there is a high correlation between active and passive travellers upon the mean RGB value of salient parts of this image (p = 0.955). This illustrates similar salient parts for each group for Image R1 (i.e. active and passive travellers looked at similar parts for Image R1). Since there were correlations among the groups upon all the salient parts of the stimuli, it can be concluded that both groups looked at similar areas. Consequently, there is no difference in landmark selection among active and passive travellers. The result from this comparison and the eye tracking analysis shows that active and passive travellers looked at similar places but for different durations (evidenced from the gaze duration analysis).

4.2. Mirror-image discrimination test

We analyzed accuracy data on the mirror-image discrimination test with a 2 × 3 repeated measure ANOVA with factors *travel type* (active/passive) and *image type* (on-route campus, off-route campus, off campus). There was a significant main effect of travel type (F1, 103 = 4.15, p = 0.4, η2 = 0.040) and of image type (F1.9, 198 = 42.63, p = 0.00, η2 = 0.293). However, the interaction between factors was not statistically significant (F1.9, 198 = 0.48, p = 0.60, η2 = 0.005). This result shows that the ability to correctly identify the orientation of visual scenes was enhanced for the active travellers (Table 4), but that this benefit was not specific to images from the test route. In addition, there was a main effect of travel type suggesting that way-finding has an effect on travel type. The main effect of images perhaps indicates that the participants have seen the scene before because they were exposed to the scene.

Results from mirror discrimination test demonstrated that active



		A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20
		B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20
		C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20
E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20
F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20
H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20
I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16	I17	I18	I19	I20
J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	J13	J14	J15	J16	J17	J18	J19	J20
K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19	K20
L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20
M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20
N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20
O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	O13	O14	O15	O16	O17	O18	O19	O20
P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20
S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20

Fig. 4. An example of a 20*20 grid, which was defined through grid index features on a selected stimuli (Image R1).

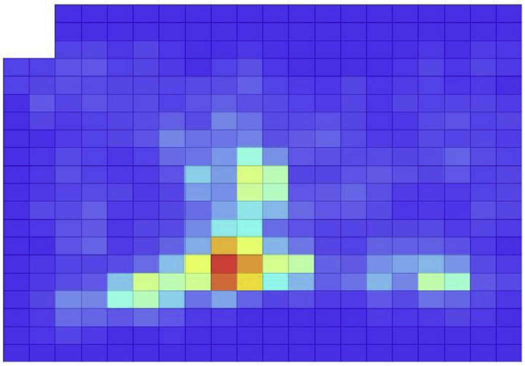


Fig. 5. Zonal statistics raster layer of active participants group for Image R1.

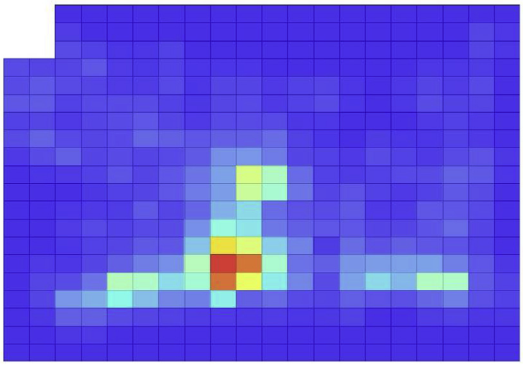


Fig. 6. Zonal statistics raster layer of passive participants group for image R1.

participants were better able to recognize the correct orientation of visual scenes from the study route than passive travellers. However, it is surprising that off-route scenes and scenes from the greater Sydney area were also discriminated more accurately in the mirror discrimination task. Therefore, it is possible that this result was caused by participants becoming more sensitive to orientation of images more generally after active navigation, perhaps by priming their navigational systems. Future research should examine this possibility more closely.

Table 3
Pearson correlations between travel type and eye movement pattern of participants for on-route images.

Stimuli	Correlations	Stimuli	Correlations	Stimuli	Correlations
R1	0.955*	R12	0.957*	R20	0.939*
R3	0.579*	R13	0.920*	R21	0.958*
R5	0.882*	R14	0.942*	R22	0.920*
R6	0.922*	R15	0.929*	R23	0.947*
R7	0.950*	R16	0.932*	R24	0.927*
R8	0.864*	R17	0.936*	R25	0.917*
R9	0.921*	R18	0.965*	R26	0.933*
R10	0.820*	R19	0.896*	R27	0.923*
R11	0.921*				

* = $p < 0.05$.

Table 4
Mean percentage of correct responses in the mirror-image discrimination test.

Travel Mode	On Route Campus	Off Route campus	Off Campus	Overall
Active	86.5 (11.3)[a]	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)

[a] Values in parentheses are standard deviations.

4.3. Spatial Ability Questionnaire (SAQ)

SAQ scales were derived from the Santa Barbara Sense of Direction Scale (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002). The average score across scales was used as the estimated participants' spatial ability. The mean score of SAQ for active and passive travellers group were 2.11 and 2.16, respectively, which shows medium level of spatial ability for both group ($t(106) = -0.42$, $p > 0.05$). Table 5 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 mirror-image discrimination 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 5
Correlations between spatial ability of participants and their performance in each test.

Correlations	Mirror-image Discrimination			Sketch Maps			Scene Recognition	
	On Route	Off Route	Off Campus	route disloc-ation	Landmark & building disloc-ation	Open space disloc-ation	On Route	Off Route
SAQ score	0.268*	0.127	0.192*	−0.121	−0.287*	−0.031	0.165	0.10

* = $p < 0.05$.

4.4. Sketch maps

Sketch maps were geo-referenced and analyzed separately in ArcMap 10.2. 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. We calculated how far each of the above factors had been sketched from the actual location by measuring the distance from the midpoint of the building and open spaces. As for route dislocation, we calculated the area between the dislocated sketched route and the actual route within a 5 meter buffer area. There is a likelihood of better results among active travellers in this task because of their exposure to the map of the campus during the way-finding task.

Three separate One-way ANOVAs were run for each of the dependent variables of route dislocation, landmark and building dislocation, and open space dislocation with factors travel type (active and passive travellers groups). The results show a statistically significant difference between groups in open space dislocation ($F1, 91 = 4.578$, $p < 0.05$), with passive travellers being less accurate than active travellers in their positioning of open spaces (−41.6 (95% CI, 80 to 3), $t(91) = -2.1$, $p < 0.05$). All other comparisons were non-significant but show numeric trends for participants in the passive group to produce less accurate sketches. Table 6 presents the mean and standard deviation for each of the six items.

Moreover, the finding that travel type, in general, and active exploration of the environment, in particular, enhanced spatial learning is in line with previous studies (e.g. Appleyard, 1970; Chorus & Timmermans, 2010; Mondschein et al., 2010). Thus, active travellers recalled spatial layout of the environment more accurately than passive travellers, by producing more accurate sketch maps. This addresses our key question in regard to cognitive maps.

5. Conclusions

We presented a triangulation method for investigating the differences between travel types in a way-finding context. We extended our study in this paper to further analyze the memory performance of active and passive travellers. The aim of this study was to assess whether wayfinding and spatial learning interacts with visual memory for scenes. We found significant differences between active and passive travellers in terms of recognition memory performance, suggesting that encoding of visual information in memory is affected by travel mode.

The advantages of active navigation for visual memory suggest that episodic visual memory plays a crucial role in way-finding. We also found better recollection of the route in active navigation, suggesting that both recognition memory and recollective memory play important roles in wayfinding. It will therefore be important in future research to examine the relative contribution of these memory processes to wayfinding.

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. But which parts of the buildings are the most informative ones? This requires future investigation of the eye movements of wayfinders in the built environment specifically in relation to visual cues. The salient visual features can inform some urban design guidelines which has an essential contribution to urban design studies particularly in relation to legibility and visual cues. For instance, this can be considered at local governments in approving Development Applications (DAs) with regard to the saliency of the design of the façade of new buildings.

The results also show that the memory performances of active travellers increased because they were directly involved in the wayfinding task. Similarly, using GPS and other way-finding aids could act as indirect way-finding (i.e. being a passive traveller). Thus, we can make the assertion that using way-finding aids can decrease memory performance. In the longer term, the use of way-finding aids can differentiate our experience of cities.

This is important not only for understanding the informative cues in the built environment but also for future urban design projects of where to focus in place making projects. Most projects in terms of legibility are limited to signage design, which is inferior when compared to building elements and open spaces.

This assertion (generalizing the findings to an urban area) requires further research and needs to be tested out in an urban area since the university campus is a controlled and pedestrianized environment and cannot easily be compared with the city where people walk, cycle, and drive a car. In addition, counterbalancing the order of tests was not possible in this study because of the nature of some of the tests that the results of them would be influenced by the results of the predecessor.

Based on our findings, a future study can suggest how to better design the built environment by enhancing urban design guidelines with more of a focus on informative and salient visual cues, those that provide more legibility to a built environment. We believe this study will aid further research in terms of visual cues and place-making and will also help to make cities more legible in future. Besides urban design implications, this study can open new insights for further investigations regarding the influence of visual memory in landmark saliency models. Moreover, the differences between two conditions can be studied further with regard to *visual attention* with a method such as mobile (glasses) eye tracker to measure and compare attention between conditions.

In summary there are four key findings from the present experiment. First, salient visual cues are informative for wayfinders disregarding travel type. Different ways of the exploration of the built environment (i.e. active and passive exploration) influence encoding of the visual cues but does not influence the saliency of visual cues.

Table 6
Mean of dislocations from the reality in sketch maps.

	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)[a]	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)

[a] Values in parentheses are standard deviations.

Second, travel type can influence the quality of visual memory (e.g. memory performance of active travellers increased). Third, travel type can influence the cognitive configuration of the built environment (e.g. better performance of active travellers in sketch map test). Finally, travel type can, in turn, influence the wayfinding performance by influencing the cognitive configuration of the built environment and visual memory of the wayfinders. In essence, we find evidence of interactions between visual memory and spatial representations of the built environment that drive way-finding processes which should be followed up in future work.

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