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Which visual cues are important in way-finding? Measuring the influence of travel mode on visual memory for built environments

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Abstract. The visual appearance of the built environment provides navigational cues for travelers that might benefit the way-finding process. Therefore, when designing built environments it is important to consider how users will respond to the characteristics of the environment during way-finding. This study highlights the importance of travel mode in way-finding processes. We conducted an experiment where participants engaged in active and passive traveler modes were asked to navigate through a pre-defined study route on a university campus. We tested participants' visual memory for landmarks by presenting photographs on a computer screen in a scene recognition task. We also measured participants' eye movements to determine which features of the landmarks were encoded in memory. Our results show an interaction between travel mode and contextual landmarks used to recognize scenes from the visual environment. Specifically, active travelers show less reliance on buildings when recognizing visual scenes. The group of active travelers appeared to use non-building cues when recognizing scenes, suggesting that these aspects of the environment had been more strongly encoded in memory. Our results can help to inform inclusive design guidelines and strategies for designing buildings, open spaces, and computer-assisted guidance applications. Furthermore, this paper introduces and applies a novel method in urban design studies that can be used to measure way-finding performance, and to examine the interaction between visual cues and cognitive processes involved in this important task.

Keywords. Contextual visual cues, eye-tracking usability, mental representation, travel mode, way-finding, urban design.

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Introduction

Way-finding is not a new topic in urban planning and architecture. Kevin Lynch was one of the most recognizable researchers in this field who had expanded theories of real-world way-finding [1]. However, aside from some recent exceptions [2, 3], very few studies have addressed the interaction between mental representation of the environment (i.e. cognitive maps) and transportation systems [4].

This study aims to find whether differences in travel mode might affect which aspects of the visual environment people attend to. To do this, we conducted an experiment where participants either navigated through a pre-defined route, or were asked to follow the experimenter around that same route. After completing the way-finding task, both groups of participants were presented with scenes containing main buildings and landmarks on the study route. Participants had to indicate whether the scene was encountered on the route or not, and we recorded their eye-movements whilst they completed this task. We hypothesized that travel mode would affect which visual features of the built environment people would attend to. More specifically, based on previous way-finding research we expected that buildings and landmarks would be subject to more visual processing by active travelers, because landmarks (among which we include buildings in this context) are thought to be important in way-finding [1, 14, and 17].

The paper is structured as follows: Section 1 presents a background in way-finding studies and limitations of previous applied methods; Section 2 shows the design of the study and methods; Section 3 presents the analysis; Section 4 discusses the results; and Section 5 presents the conclusion and future work.

1. Way-finding and visual cues

Way-finding involves selecting a pathway from an origin to a destination. It is the ability of travelling between locations either with an internal or external map of the environment [5]. Further, way-finding behavior requires purposeful and directed *movement* from an origin to a specific distant destination [6].

Furthermore, way-finding is a behavior [7] that involves many cognitive processes: The traveler must know where they are, know where their destination is, follow the best route to their destination, recognize the destination, and finally find their way back to the origin [11]. Accordingly, it is the process of collecting information from our *built environment*, to know where we are related to where we want to go and how to get there. This process can be completed through gathering information from any objects which we refer to as *visual cues* in this paper. Consequently, such behavior involves interactions between the *traveler* and the *environment* [9].

Visual cues are reference points or any landmarks and signage that people refer to while they are travelling within cities. Sorrows and Hirtle defined landmark as a prominent object individuals use as a reference point to help them in memorizing and recognizing routes as well as locating themselves in terms of their ultimate destination [10]. Hong stated his definition of landmarks in the context of spatial knowledge [11]. He believed that the basic representatives to the cognitive map, which can be called landmarks are geometric components including points, lines, and polygons. Thus, the major role of landmark is supposed to be the spatial reference point.

Recent studies by Mondschein et al. (2010), Chorus and Timmermans (2010), and a previous study by Appleyard (1970) show evidence of the relationship between travel mode, and cognitive maps. Such studies suggest that using different travel modes will influence the understanding of the same environment in different ways. Likewise, they found that active modes increase individuals' perception of the construction of urban space. In these studies, active travelers are defined as pedestrians or those using active modes of transport such as cars or bicycles, - navigating through the city without guidance. Passive travelers are people that do not navigate through the city themselves, such as those who travel by bus, train or taxi [2, 3].

Mondschein, et al. studied different experiences of travel mode shaping the cognitive map by measuring the accuracy of cognitive mapping with regard to distance and a particular location in the cognitive map [2]. They compared different travelers in regard to using landmarks and estimating distance to landmarks, remembering street names, and familiarity. The authors found that differences in modal travel experiences are associated with differences in the content and construction of individual's cognitive map. Accordingly travel mode affects how individuals perceive the built environment. In their study, they designed a survey to collect data from respondents. When estimating distance to landmarks, passive travelers overestimated the distance of landmarks and were more uncertain about the distance relative to active travelers. Thus, according to this study [2], experience of travel mode shapes one's cognitive map.

Chorus and Timmermans studied the observed and self-reported quality of people's cognitive construction of urban space and assessed the effect of sociodemographic factors in combination with travel mode on this mental construct [3]. They investigated whether the findings of [2] and [12] can be replicated in the context of a different population. Respondents were asked about how they themselves assess their cognitive knowledge of the selected urban area (self-reported) in comparison with the real ability they had (observed). They inferred from the self-reports that respondents were between poor and reasonable[2] in finding their way within Eindhoven (study area). As a result, the study finds that using active modes increase a person's perception of the quality of their construction of urban space and has a positive effect on revealed quality. This result supports the studies of [2, 12]. Besides, it is still vague that which landmarks or visual cues absorb active travelers' and passive travelers' attentions, disregarding the *passive immediate sensorial attentions*.[3]

Xia, et al. proposed four conceptual models based on the level of familiarity of tourists [14]. All the participants were active travelers who experienced way-finding in Kuala Conservation Centre by walking. Even though [14] noted the mode of transport in their conceptual models, more attention in the survey was paid to different types of landmarks utilized by diverse gender as well as the level of familiarity of users. They found different landmarks people use are related to the level of familiarity with the environment. Importantly however, this research did not assess the effect of way finding on the use of landmarks, because they did not recruit a group of passive travelers to act as a control.

Although way-finding and travel mode have both been studied extensively, research has not investigated the *interaction* between these issues. Instead, these topics have tended to be treated as separate issues. For example, much work has been devoted

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[2] The categories of the responses were: poor, reasonable, good, and very good.

[3] This kind of attention relates to a sudden attention, which is not relevant to the nature of the object [13].

to travel mode from transport engineering or planning viewpoints and to issues like distance, cost, and time. However, no study examines the role of travel mode on and in relation to the way-finding process, except [14], which mainly focuses on the effect of familiarity, gender, and landmark utilization on this process. In addition, way-finding is an interesting subject of study for both architects and psychologists. Many studies focus on navigating building interiors, however outdoor travel is typically limited to natural environments [14], in urban studies it is limited to graphic design such as form, height, and color of signage.

More importantly, the effect of travel mode on the way-finding process might not be limited to changes in cognitive mapping – which is the focus of previous research – it might also affect the way that the built environment is initially processed by our visual system. Because episodic memory representations have not been studied in this context, a significant portion of our memory for the built environment has been neglected in previous research. Therefore, in this study we aim to investigate the extent to which travel mode affects scene recognition processes using an eye-tracking methodology.

Eye-tracking usability has recently been introduced in way-finding studies [15]. In this study we set participants' a way-finding task, and use eye-tracking apparatus during a subsequent memory test for visual scenes, to infer how travel mode affects memory for visual cues during way-finding.

2. Method

2.1. Participants

Fifty-four students (31 female) from UNSW participated in this study. Half of them were exchanged for extra credit in psychology courses and the rest were volunteered students whose names were put into a prize draw for their participation which last approximately 80 minutes. Participants' ages ranged from 17 years to 58 years with the mean age of 24.5 years.

Because familiarity has a large effect on the way-finding process [14], we selected participants that were either familiar or partially familiar with the university campus in which our experiment took place. The route through the campus was designed such that it required navigation through areas of campus that are not common thoroughfares, do ensure that participants in the active condition could not rely on familiarity for navigation.

2.2. Procedure and design

Participants in this study each completed five tasks: i) outdoor way-finding task, ii) questionnaire, iii) semi-structured interview, iv) mirror-image discrimination test, and v) scene recognition test. Due to the preliminary nature of this research program, here we present only results from the Scene Recognition Test.

We designed this experiment to test two hypotheses. First, active travelers would be better at recognizing visual scenes due to their enhanced visual processing of the build environment during way-finding. Second, there would be a difference between active and passive travelers in terms of the visual cues that they used to perform this recognition task.

To measure this, and based on previous eye-tracking research, we assume that the areas of the image that are attended to in the Scene Recognition Test are those features that were encoded in memory during the way-finding task [18]. Therefore, the differences between features used by passive and active groups in the Scene recognition test are assumed to be the aspects of the built environment that were specifically used in active way-finding.

2.2.1. Outdoor way-finding task

To test the effect of travel mode on visual memory for travel route, we set participants a way-finding task. Participants were provided with a paper map illustrating three landmarks (1, 2, and 3) and three cards relating to each landmark and containing a question on each. They were instructed that they would have to use the three landmarks on the study map to answer three questions related to each landmark.

For participants in the Active Traveler group[4], we instructed them to follow the study route and to complete the way-finding task themselves. The participant was accompanied by the researcher during the task, but did not navigate and walked behind the participant at all times. Whenever the participant made a mistake and got out of the Study Route, the researcher asked the participant if s/he needs any help to provide orientation cues to guide the participant back to the study route.

Passive Travelers did not perform way-finding, but were instead led by the experimenter through the study route to each of the three landmarks. When arriving at each landmark, the researcher notified the participant to answer the related question. Both groups were asked to pay attention to their surroundings during the navigation task as they need to recognize some views from the study route in the subsequent tasks.

2.2.2. Scene Recognition Test

Fifty-four images were shown to the participants; each image was shown for 5 seconds[5] on the screen. Participants were instructed to indicate after each image had been presented whether they recognized the view from the study route or not. This task was identical for both groups of active and passive travelers. The order of the presentation of the images was randomized.

During this task we recorded participants' eye movements using a static eye-tracker (Tobii TX300). Specifically, we recorded fixation duration, fixation count and visit duration for three Areas Of Interest (AOIs) in each image. Fixations to AOIs were chosen as the main dependent variables because previous eye-tracking research has shown that measures of fixation indicate where on an image attention is being allocated [19]. Furthermore, research has shown that there is a large correspondence between eye movements to the same image during study and test phases of recognition memory tasks (see [23] for a review). This is important, because it suggests that the visual cues

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[4] An active traveler is a person who is actively and directly involved in the way-finding decision-making task in contrary to a passive traveler. In this paper, we differentiate between an active or a passive traveler and a person who is using active or passive modes of travel. In this regard a driver who is guided to a destination is not an active traveler. Additionally, a passenger in a taxi is an example of a passive traveler. Note that there is another group in between being an active or passive traveler which is the mixed-group. An example for a mixed-group is a passenger in a bus who is a passive traveler in some parts of the journey but alter to active mode while s/he requires to make a *decision* where to get off.

[5] Five seconds is in justification of the amount of sufficient time for an observer to view the scene without losing his/her attention. It is based on previous psychological experiments.

which our participants attended to during the way-finding task would be the same visual cues they attended to in the subsequent Scene Recognition Test.

During piloting we selected images for use in the Scene Recognition Test using a mobile eye-tracking device (Tobii ultra-lightweight glasses with 30HZ recording frequency). We recorded the eye movements of eight pilot participants (half Passive Travellers) to identify scenes that were attended to by both groups. Examples of the images used in the Scene Recognition Test are shown in Figure 1.

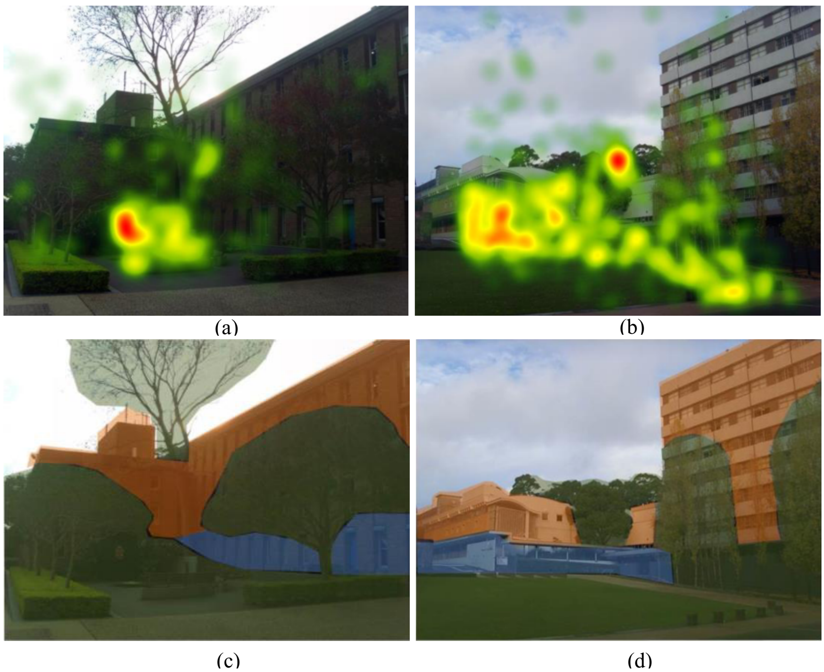

Figure 1. Examples of heatmaps from aggregate data of both groups of active and passive travelers; a) an example of non-building features which fixated longer; b) an example of non-building (path) and first floor; red points indicate places fixated longer; c) and d) examples of AOIs; Blue: First Floor, Orange: Upper Floors, Green: Non-buildings.

3. Results

Four separate analysis of variance tests (ANOVA) were conducted, one for each dependent variable collected in this experiment (accuracy on Scene Recognition Task, and three measures of eye movement behavior – see below). For accuracy data, we carried out a mixed factor ANOVA with between-subjects factor of Travel Mode (active, passive) and within-subjects factor of Image Type (on route, off route).

The three dependent measures were: fixation duration, fixation count, and visit duration (or 'dwell time'). Fixation duration shows for how long the eye was still in a particular Area Of Interest (AOI) [16], and is often interpreted as an index of cognitive processing to specific area of an image. Fixation count measures the number of fixations to an AOI, showing the density of fixation behavior in that area. Finally, visit duration is the length of time for one visit in an AOI from entry to exit, which is similar to fixation duration in several ways but usually longer in duration as it is the sum of several fixations which provides an aggregate of total fixation behavior in a given trial [16]. Visit duration can either index the informativeness of AOIs, difficulty in extracting information from them, or in some cases uncertainty [19]. For each eye-tracking variable, results were analyzed with mixed factor ANOVA with between-subject factor of Travel Mode (active, passive), and within subject factors of ImageType (on route, off route) and AOI (building first floor, building upper floors, non-building).

3.1. Recognition memory performance

A two-way ANOVA was calculated on the percentage of correct responses made by participants in both groups of active and passive travelers (i.e. correctly classifying an image as either on-route or off-route). Our analysis revealed a significant main effect of Travel Mode, $F_{1,52} = 3.961$, $p < 0.05$, $\eta 2 = .07$ but not main effect of Trial Type, $F_{1,52} = 0.802$, $p = 0.374$, $\eta 2 = .01$, and no interaction between factors, $F_{1,52} = 1.322$, $p = 0.25$, $\eta 2 = .02$. Thus, participants in the Active Traveler group were more accurate in the Scene Recognition Test than Passive Travelers. Table 1 shows summary statistics for each experimental group on the Scene Recognition Test.

Table 1. Mean percent correct for experimental groups in the Scene Recognition Test (standard deviations in parenthesis)

Travel Mode	Correct Response On Route	Correct Response Off Route	Overall
	Mean (Std. Deviation)	Mean (Std. Deviation)	Mean (Std. Deviation)
Active	84.5 (12.4)	85.2 (12.1)	84.9 (12.2)
Passive	81.9 (12.8)	76.4 (19.1)	79.2 (16.0)

3.2. Eye tracking analysis

Average data for the three eye-tracking measures are shown in Figure 2. We ran separate three-way mixed factor ANOVAs (see above) for each of the eye-tracking measures. In this analysis, we were specifically interested in the interaction between Travel Mode and AOI, which relates directly to our experimental hypothesis that travel mode would affect the visual cues processed by participants during way-finding. This interaction effect was non-significant for Fixation Duration, $F_{2,104} = 2.60$, $p > 0.05$, $\eta 2 = .048$, and for Fixation Count ($F < 1$). However, for Visit Duration the interaction was significant, $F_{2,104} = 3.22$, $p < 0.05$, $\eta 2 = .058$.

Given the significant interaction between Travel Mode and AOIs for the Visit Duration, we explore this interaction further using planned-comparison t-test. Quite surprisingly, this analysis showed that the interaction effect was driven by a *greater* reliance on non-building cues in the Active Traveler group, $t\,(52) = 1.99$, $p = 0.051$, but not in first floor, $t\,(52) = -1.34$, $p = 0.18$, and upper floors, $t\,(52) = .78$, $p = .43$.

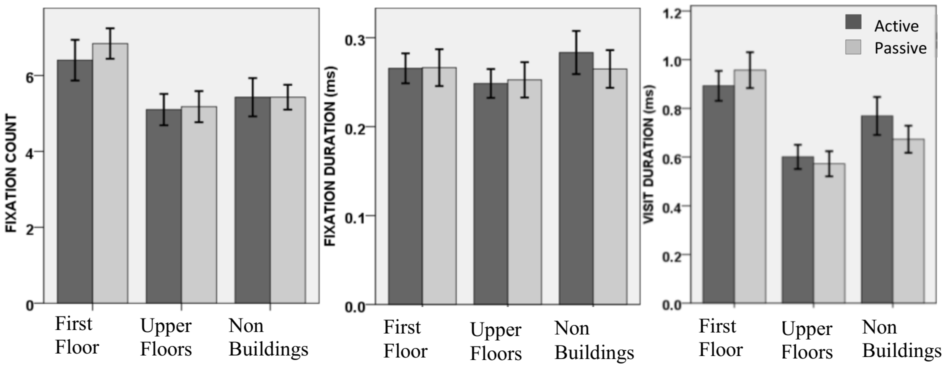

Figure 2. Summary data for eye tracking measures in the Scene Recognition Task (fixation count, left; fixation duration, middle; visit duration, right). Error bars represent Standard Error of the mean.

In summary, the two-way interaction between travel mode and AOI was observable only for Visit Duration. This was caused by a greater amount of time spent fixating on non-buildings regions in the Active Traveler group. Therefore, active travelers would appear to have processed visual cues (such as paths, vegetation, signage and furniture) more that passive travelers, because they relied on this information more heavily when recognizing scenes from the study route. We interpret this as evidence that non-building features of the built environment are important in way-finding.

4. Discussion

This study empirically examined the influence of travel mode on visual processing of the built environment. We investigated how travel mode affected the ability to access visual memory. The results from the Scene Recognition test (section 3.1) show that active travelers were better at recognizing visual scenes from the study route, suggesting deeper processing of visual information in this group. In addition, our eye-tracking analysis revealed that active travelers looked longer at objects and landmarks that were not buildings in the recognition test, which suggests that these visual cues were important (i.e. processed more) during active way-finding. We interpret this as partial support of our hypothesis that travel mode affects which visual cues participants attend to and process during way-finding. This implies that travel mode can influence the visual attention.

Our analysis supports findings obtained from [2], [3], and [12] on the quality of people's cognitive construction of the built environment in relation to travel mode. Being an active traveler enabled people to be involved more in way-finding in the built environment. We can extrapolate the results of the interaction between the built environment and travel mode by discussing more detailed relationships of both landmarks and people, and paths and people. This statement is relevant to the LRS model, a knowledge-based model which describes three components from which spatial knowledge can be acquired: Landmark, Route and Survey knowledge [20].

Prior landmark knowledge, which enables people to move from one landmark to another [20], was almost equal among participants. Each participant was either familiar or partially familiar with the campus site. However, landmark knowledge did not come only from their previous familiarity with the site, but was increased during the way-finding task.

Route knowledge develops by connecting landmarks [20], which contains a sequence of memory of how to get from each point to the other [21]. Providing active travelers with the map, in this study, increased their route knowledge and allow them to jump to the survey knowledge [20]. Therefore, passive travelers may lack this process of connecting landmarks with route, as they haven't been involved in navigation directly. Reading the maps could have increased the survey knowledge among active travelers. Thus, it might be the enhanced process of survey knowledge among active travelers which enable them to perform better.

Survey knowledge refers to integrated knowledge of the layout of a space and the interrelationship of elements within it [22], such as symmetry, continuity, and visual access. This can reveal the differences between groups in visualizing the environment and show how travel mode can modify the way people are processing visual environmental information. It appears that travel mode can increase active travelers' spatial ability in way-finding.

The relationship between places and the interrelationship between elements within the places are the two intangible and notable factors which can influence way-finding performances. Perhaps, this interaction is more noticeable in visual processing of the built environment and among active travelers.

5. Conclusion and future work

In this paper we presented a novel method for way-finding and urban design research, where we built upon the work of [15]. The design of the study is drawn from the formulation of a hypothesis, which indicates differences on landmark utilization among users with different modes of travel in a way-finding process. We now have evidence on the applicability of the eye-tracking device in urban design fields. Future work in urban design fields which require interdisciplinary studies with psychology can benefit from using the eye-tracker device. It would be of interest particularly in case studies which require observing the behavior of the participants passively.

We found evidence for differences between active and passive travelers in their attention to visual cues. Our findings suggest that differences exist between active and passive travelers conducting way-finding task. However, the visual cues that they refer to, and the extent to which they differ, have not been studied. A finer breakdown in AOIs could yield to better results that might help determine the informative cues and to figure out the characteristics of these visual features.

Taken together, we have shown that what makes active travelers perform better is their more completed survey knowledge of the built environment compare to passive travelers; which encompasses the inter-relationships of elements in a built environment, and the linkage between routes and locations. More complete survey knowledge led to a better configurational construction of the built environment, which is a consequence of a legible design of the built environment. The research placed emphasis on using inclusive design or universal design of the way-finding system for all users, irrespective of travel mode.

The main goal of our future research will be to perform an item analysis on the images to find the common characteristics among visual features that participants had fixated on longer. Many directions for future research can be led from this work. The usefulness of the method can be tested in a more complex environment to broaden the applicability of the method. Another interesting area for future work could be the analysis of façade designs, place making, and the relations between places and spaces in order to increase legibility in urban environments. Future research can look to further understanding of relationship between survey knowledge among active and passive travelers in way-finding studies.

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