What Lab Eye Tracking Tells us about Wayfinding A Comparison of Stationary and Mobile Eye Tracking in a Large Building Scenario

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Abstract. Eye tracking has become a common method for addressing different topics in the domain of spatial cognition. However, most studies use stationary eye tracking devices to get insights into the cognitive processes of spatial navigation and wayfinding. We argue that these studies may miss important factors, because body movement and orientation as well as the complexity of real-world perceptions have a strong influence on the processing of environmental information and on spatial decision making. We propose conducting lab and field studies using stationary and mobile eye tracking devices to investigate the degree of comparability of these accounts and to ensure the ecological validity of lab-based eye tracking studies in spatial navigation tasks. We aim to identify the criteria for designing insightful lab-based eye tracking studies in the spatial domain.

Keywords: Mobile Eye Tracking, Wayfinding, Spatial Decision Making, Ecological Validity.

1 Introduction

Over the course of the last decade, eye tracking has been employed in an increasing number of studies on spatial cognition. Research on spatial decision making is rooted in visual perception research paradigms that use stationary eye tracking to analyze gaze behavior [1], whereas virtual reality (VR) settings and field studies that dominate the experimental work in wayfinding research only rarely include an analysis of gaze behavior. Thus far, only few studies on spatial cognition have examined gaze behavior in real-world wayfinding tasks (e.g., [2], [3]). A small number of studies provide convincing evidence that eye-movements in the lab are, in many respects, comparable to eye-movements in the real world [4], and that eye tracking analysis can be used to investigate spatial cognitive processes and to predict wayfinding behavior in real-world situations [5]. However, a direct comparison of lab-based and real-world gaze behavior in this domain has not yet been achieved. Thus, we hereby outline a project in which we intend to compare the approaches of lab-based eye tracking on the one hand and mobile eye tracking in highly complex real-world settings on the other hand. This project will provide insights into the perception and processing of visual information (e.g., signs) during spatial navigation in a large indoor environment, and aims to validate lab-based eye tracking findings on spatial decision making in the field.

2 Gaze Behavior in Spatial Decision Making

Throughout the last years our group has studied human gaze behavior in lab-based spatial tasks. For example, we investigated visual attention during spatial decision making [1]: Participants who were asked to search for a hidden object using screenshots of a large VR environment tended to first search in the direction of the pictured area with the longest line of sight. Additionally, we found a robust gaze bias towards the direction that was finally chosen and developed a bottom-up-model to predict participants' fixation behavior on the basis of the spatial features of the building [1]. We also investigated the relationship between spatial decision making and visual attention in a route learning paradigm [5]. Participants were passively moved through a VR building. Afterwards, they saw static images of the intersections and had to decide where to move in order to follow the previously learned route. We replicated the gaze bias and were able to manipulate it depending on the uniqueness of the landmarks. Taken together, we showed that gaze bias is an important part of visual decision making and developed a model of gaze behavior. However, our findings are limited in that we used simple stimuli with little visual clutter whereas humans navigating space in the real world must deal with complex perceptual input [4].

More closely related to real-world visuospatial complexity, we aimed at improving the usability of the signage design in an airport in another series of experiments. We employed a methodological triangulation approach to support the design process of signage solutions at several critical locations and to advise the operators of the airport on the positioning of their signage [6]. We used a stationary eye tracking device (EyeLink1000) and presented rich static images of the airport indoor environment, such as photographs and snapshots from detailed VR environments, either with the status-quo signage or digitally edited with re-designed signage. Participants were asked to decide which direction they would choose to find a specific location (i.e., a gate) as quickly as possible. We measured participants' accuracy, reaction times and gaze behavior and showed that they made fewer errors, decided more quickly, and were more focused on the important information with the re-designed signage than with the status-quo design. This approach was replicated at another location in the airport where we additionally asked participants how confident they felt about their decisions. Re-designed signage not only led to gaze behavior that was more focused on the relevant information, but also increased participants' subjective confidence. Our studies supported the airport operators with information about the most user-friendly design solutions, which were subsequently realized. We refined this combination of behavioral data, self report, and eye tracking to a method assessing the effect of signage in buildings *even before the respective building is built* by using renderings from a VR model [6].

3 Mobile Eye Tracking in Spatial Cognition Research

In the airport scenario, we used realistic and complex stimuli. We will continue and extend this approach by presenting participants with video clips of locations at the airport. However, this approach still lacks the aspect of locomotion – participants do not move their bodies through space. The more complex sensory input of a real-world scenario as compared to a well-controlled lab setting may have an influence on spatial decision making and wayfinding [4]. Furthermore, while walking through a building, the body's movement and its orientation continuously change the visual perspective on a scene.

The rapid advancement of technology in the past decade now enables the efficient deployment of mobile eye tracking devices for a more direct investigation of cognitive processes in the field [7]. However, mobile eye tracking provides new challenges as compared to lab-based approaches, both due to subtle differences in gaze behavior [4] and an increased complexity of data quantification. To date, only a few studies have used mobile eye tracking in connection to locomotion and wayfinding. Two of these studies linked gaze behavior to simple stepping patterns [8] and examined how advancing pedestrians affect gaze behavior [9], respectively. More closely connected to our project is a case study in which participants received realistic wayfinding tasks in a train station [2]. A qualitative analysis of gaze behavior, wayfinding performance, and thinking aloud was used to advise the train station's operators in their design and placement of signs. To our knowledge there is only one study [3] that aimed to quantify gaze behavior in wayfinding tasks and used mobile eye tracking to analyze pedestrian map usage in an urban context. A current approach combines mobile eye tracking with location and head tracking in large outdoor environments [10]. However, it is an open question whether eye tracking studies in the lab have the necessary external validity as compared to real-world observations in the field. Thus, an analysis of gaze behavior in relation to navigation and sign reading is highly desirable. This will help establish criteria for the design of insightful eye tracking studies in the lab for spatial navigation research.

We plan to tackle this challenge in an extended cooperation with the airport. In our studies participants at the airport will perform a series of subsequent wayfinding tasks (e.g., "Find Gate A23!") closely related to the tasks in our lab studies to validate our former findings. We will use state-of-the-art mobile eye tracking devices (SMI) for qualitative and quantitative analyses of gaze behavior towards signage as a central indicator for the use of signs in complex urban environments. Eye tracking measures will include the time from the first appearance of a target object (e.g., a given sign) to the first fixation on the target object, as well as the overall number and overall time of fixations on the target object. In order to maximize the comparability of the scenarios, the data collection in the first studies will be conducted at very low crowd density as there was no distraction by other passengers in the lab, and crowd density will be adjusted to regular passenger density in the later studies. Additionally, we will perform a behavioral observation of the participants. After the wayfinding task, participants will comment their own gaze behavior in a retrospective thinking-aloud task. The qualitative analysis of this task will provide further insights into passengers' orientation strategies. We expect comparable sign detection probabilities, wayfinding performance, gaze behavior, and erroneous decisions to our lab findings. If we show differences between these settings, we will elaborate how to deal with the identified factors in future lab studies.

4 First Steps

In an exploratory pilot study at the airport, we aimed to replicate the setting of one of our lab studies [6] with mobile eye tracking devices, and confirmed the general feasibility of this approach. The eye tracking devices proved to be unobtrusive enough to have no disturbing effects on individual behavior or on other passengers. Figure 1 depicts the heat map of participants' gazes on an airport location situated in a recently built terminal area as it was tested prior to its construction in the lab, and a respective

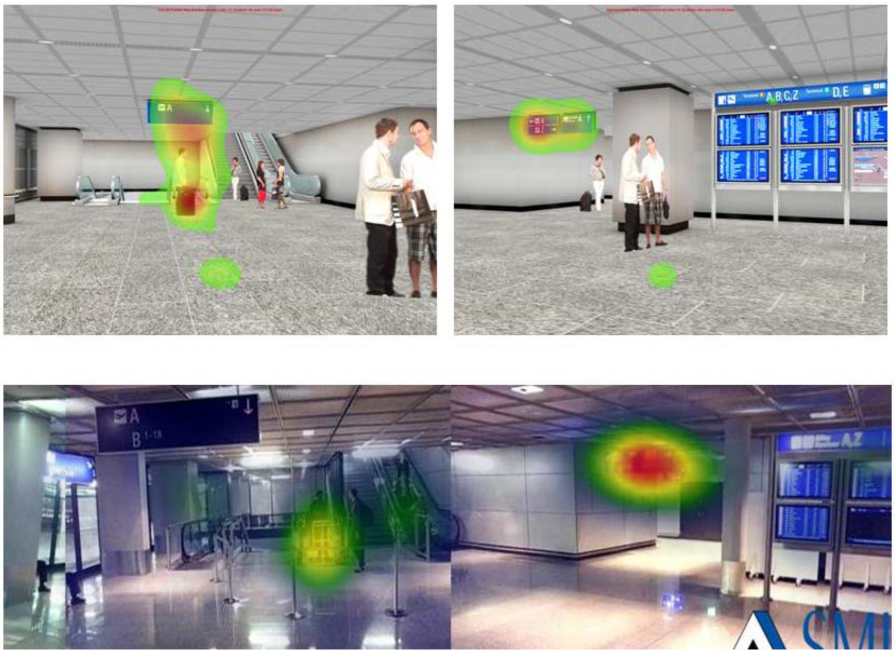

Fig. 1. Heat maps of a newly built area looked at on two subsequent, static slides in a lab study (top) before the construction of the building as compared to the heat map of the same terminal after construction derived from mobile eye tracking videos recorded at the airport (bottom). Red and green, areas indicate a high and low number of overall fixations respectively.

heat map of participants' gazes at the same area from our field study. In the lab study, this terminal area was looked at on two static slides, whereas the heat map of the field study results from the analysis of gaze behavior during walks through this area. Despite these differences, the descriptive analysis implies that gaze behavior in both settings is largely comparable, with strong foci on the right sign and the descending escalator.

However, Figure 1 also demonstrates some differences between lab and field studies: The left sign was studied intensively in the lab study, but basically ignored in the field study. Reasons for this difference are, first, that this sign was the only visible sign in the lab study and there were no competing signs as in the pilot study. The real environment also contained noticeably more peripheral objects than the static images from the lab study. Additionally, other travelling passengers were present in the pilot study. Although the data collection was conducted at very low crowd density in order to maximize the comparability of the scenarios, there was no distraction by other passengers in the lab. Second, the positioning differed between the settings due to the exploratory nature of the pilot study, with the sign being located closer to the escalators in the planned setting as compared to its subsequently realized position (sign positioning will be held constant in future studies). Third and most importantly, this terminal area was entered through a revolving door on the left in the field study and the sign was passed before it was noticed by the participants. These observations indicate that body orientation and movement have a strong impact on the perception of signs that cannot be captured in lab studies, and thus emphasize the importance of mobile eye tracking directly in an environment in addition to eye tracking in lab studies. On the first glance, these differences appear to limit the validity of this comparison. However, they also point out crucial aspects in real environments that may not be adequately addressed in lab studies.

5 Summary & Outlook

The comparison of stationary and mobile eye tracking is a crucial step to underpin former findings on spatial decision making in wayfinding tasks. The replication of lab findings in the field will provide insights in the relationship between gaze behavior under lab conditions and in the field and ensure the validity of stationary eye tracking findings on spatial cognition. In our future work, we will conduct field studies in a large building environment to focus on aspects of gaze behavior in real environments that go beyond the possibilities of lab studies. For example, mobile eye tracking allows for the investigation of two cooperating passengers and how this social interaction affects gaze behavior in relation to a wayfinding task. Finally, we will conduct controlled behavioral experiments in our lab using mobile eye tracking devices in a VR model of the environment. This allows using the mobile eye tracking field data to systematically vary specific factors in the lab without losing the added value from spatial stimuli and participants' body movements. Hereby the validity of a more immersive VR-scenario as compared to stationary eye tracking with static images and mobile eye tracking in the real environment can be evaluated.

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