A Comparison Study of Stationary and Mobile Eye Tracking on EXITs Design in a Wayfinding System

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***Abstract*—"Wayfinding system" is an interdisciplinary research between the environment design and human interface of information system. The design of EXIT is to efficiently help people to identify the emergency exit when the accident occurred. In this paper, eye tracking techniques are utilized to aided EXIT design in the wayfinding system. The mobile eye tracking was used to collect the human eye movement data in the building where different EXIT designs were displayed. While the stationary eye tracking techniques was used to collect the eye movement data on the same building's EXIT designs on virtual 3D sketches to get the quantitative data comparing with the mobile eye tracker. Finally, some general conclusions were obtained from the views of visual elements selecting, EXIT appearance design and EXIT's placement in the building, which is very valuable and can be commonly referred in wayfinding system. The research methods in the paper is very original and has not been mentioned in other papers of the related fields before, which is well worthy data and empirical methodologies can be introduced in wayfinding and space decision making research.**

***Key words*—Eye gaze tracking techniques, wayfinding system, space recognition, space decision making, eye tracking metrics**

I. Introduction

Eye tracking techniques aim to precisely and nonintrusively trace the point of gaze of human being. It opens a window and acts as a special tool to both qualitatively and quantitatively measure the untouchable human consciousness and behavior, which has caught great interests of scientists from different areas and interdisciplinary subjects, such as neuroscience and cognition and psychology, industrial engineering, commercial marketing, computer science and etc.[1]

Wayfinding is a process that people engage in on a daily basis which can be described as purposeful, directed, and motivated movement from an origin to a specific distant destination that cannot be directly perceived by the traveler [2][3]. People must utilize spatial decision making and various cognitive to accomplish the specific tasks included in wayfinding, such as choosing a route, maintaining orientation, and recognizing any signage inside or outside the building [4]

Over the recent years, 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. For example, Grasso et al [5] demonstrated anticipatory gaze behavior when walking along curved paths. Similar results also come from steering experiments: when driving a car around a curve, drivers gaze at the tangent point on the inside of the curve [6][7]. Furthermore, Schuchard et al's [8] work gradually began the research on spatial visual signs' recognition. In their papers, eye tracking data were collected from dementia patients navigating the hall ways of a nursing home. The patients showed a lack of ability to attend to critical signage, but predominantly focusing on the lower parts of their visual field, presumably concentrating on motion control issues (i.e., the locomotion-component of navigation). Spiers and Maguire [9] present eye-tracking evidence on taxi drivers' pattern of visual attention in a VR driving simulation of London. Finally, Allen and Kirasic [10] , using a slideshow paradigm similar to the one applied in the present study, identified difference in visual focus between scenes with high versus low density of special signage cues.

In those eye tracking studies, only stationary eye tracking techniques are utilized. The advantages of stationary eye tracking techniques is the high qualified sampling data, simple operation and non-intrusive to user. But those spatial cognition tasks are transferred by virtual reality (VR) and the real scenario 3D study is converted to 2D situation, which doesn't reflect the relationship between the real gaze distribution and steering behavior in the spatial object recognition. While, mobile eye tracking techniques, namely the head-mounted eye tracker, can be used in the real dynamic 3D environment to obtain the real-time eye movement data to solve the problems caused by stationary eye movement techniques.

However, compare to the stationary eye tracking techniques, mobile eye tracking techniques have a certain degree of difficulties, because on the one hand there are some limitations and requirements to manipulate the head-mounted eye tracker in the real 3D scenarios. On the other hand, the data collected by head-mounted eye trackers cannot be automatically matched with the spatial dynamic visual target, which is currently carried out by manually matching. As a result, there is almost no related research report on the mobile eye tracking on exits design in a wayfinding system.

In this paper, we are the first to present the comparative study of stationary and mobile eye tracking on exits design in a wayfinding system which is very original and not been mentioned in any other papers till now. In the rest of this paper, We firstly put mobile eye tracking techniques into operation to qualitatively estimated the pros and cons of each groups of visual elements such as EXIT content, out appearance and location in the building . Then we build the 3D model of the real building to precisely reconstruct the building with different EXIT design on 2D screen plane to do quantitatively estimation on each design's performance with more detailed eye tracking metrics. By such a thoroughly and deliberately comparative study, many correlated design elements and unbounded decisions can be qualitatively chosen and quantitatively narrow down. Finally, the study provides some general conclusions for EXIT's design inside a building, which is well worthy data and empirical methodologies can be introduced in other space decision making researches.

II. The Visual Elements and Design Decisions of EXITs Inside a Building

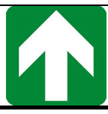
A. The visual elements of EXITs

An emergency exit in a structure is a special exit for emergencies. The combined use of regular and special exits allows for faster evacuation. When creating signage for emergency evacuation, a high number of constraints have to be taken into account in order to come up with a viable solution.

1) The EXIT's content.

On the whole, there are three types of content for emergency exit sign design, text, icon , arrow symbol. Overall speaking, as shown in table I, both text content and icon content are more often used on the building's vertical walls, the arrow symbols are used on the floor for the most part.

TABLE I. The EXIT's contents

Text	Icons	Arrow Symbols
		

2) The EXIT's appearance.

As presented in table II, considering the visual significance of EXIT sign in different building environment, the out appearance can be classified into with or without power supply. Besides, the different EXIT colors can be rendered in the different architecture environments.

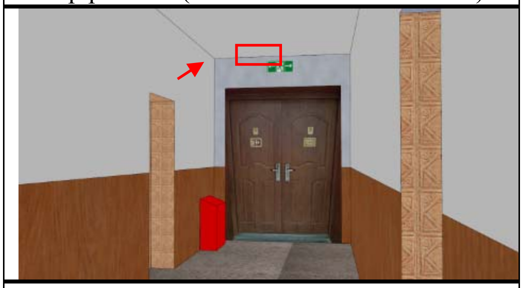
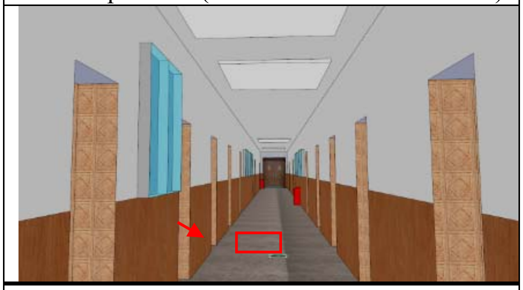
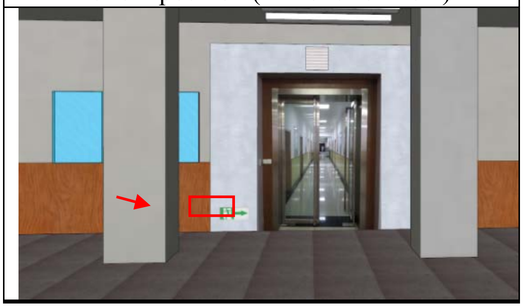
TABLE II. The EXIT's out appearance

With power supply	With night luminous	Green	Red	Blue
				

3) The EXIT's location.

Nelson and Loftus [11] found that the space object is easily recognized if it located within the 2.6° visual angle near the fixation point. As a consequence, the placements of EXIT signs have a remarkable influence on the efficiency of people evacuation during emergency. As given in table III, there are basically three types of positions, top, bottom and ground.

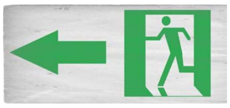
TABLE III. The EXIT's location

Top position (normal office environment)

Ground position (normal office environment)

Bottom position (hall environment)


B. Four types of candidate EXIT designs and their expectation.

We comprehensively consider various visual elements of EXITs design and its location. From the view point of content, we consider icon, arrow and text as different design element. From the view point of out appearance, we directly utilize the no power supply design and the "white + green" and "white + red" combinations, which are always, have the best visual saliency compare to other no supply designs. From the view of location, it can be divided into two categories, ground location and non-ground location. Because according to the interior design experience, the ground location is always attract more visual attention as long as can be seen. But the ground location cannot take place of other locations inside the building because of its higher cost and the possibility of being covered in an emergency, as a result, four types of candidate EXIT designs, their expectations and the features of those visual elements are listed in table IV.

TABLE IV. FOUR TYPES OF TYPICAL EXIT SIGNAGE DESIGN AND THEIR EXPECTATION

Design	Expected effect	The features of the visual elements
NO1: ”Icon” + ”Arrow”  	**Good**	Such design is very clear at a glance; visual information transmission efficiency is highest. “White + Green” pair has the best saliency according to human vision compare to other design.
NO2: ”Text” + ”Arrow”  	**Average**	Although the text explains the function of the sign, but such design lead to a very low efficiency of information transfer. So the experiment effect is expected to be average.
NO3: ”Text”+ ”Icon”+ ”Arrow” 	**Poor**	Such design increases the visual information workloads burden, which is adverse to help the evacuation. So the experiment effect is expected to be poor.
NO4:”Ground”: 	**The best design among all location**	Among all the location, the ground location is the best. The design use “green ground + white content” which is also the best expected design.

III. THE RESULT AND DISCUSSION OF THE COMPARISON STUDY OF STATIONARY AND MOBILE EYE TRACKING ON DIFFERENT DESIGN OF EXITS

A. The setup of the head-mounted eye tracker experiments and results

We carried out 12 persons and 23 persons real-scene mobile eye tracking experiments to test the visual saliency of four types six EXIT designs. Tobii Glasses [12] is used as the mobile eye tracker in this paper, which is monocular sampling (right eye), sampling rate is 30Hz. In general, the head-mounted eye tracker can only collect single sample person’s eye tracking data one by one, but can’t combine the entire tester’s eye tracking data together, owing to the disadvantage of the scene camera is head-mounted. We apply IR Marker to solve this problem in this paper. IR Marker is an infrared-light transmitter which can communicate with the IR Marker sensor on the head-mounted eye tracker. Four IR Markers can group an AOI (Area of Interests) that can be used to aggregate gaze data for quantitative analysis and to make visualizations such as gaze plots and heat maps using data from multiple participants.

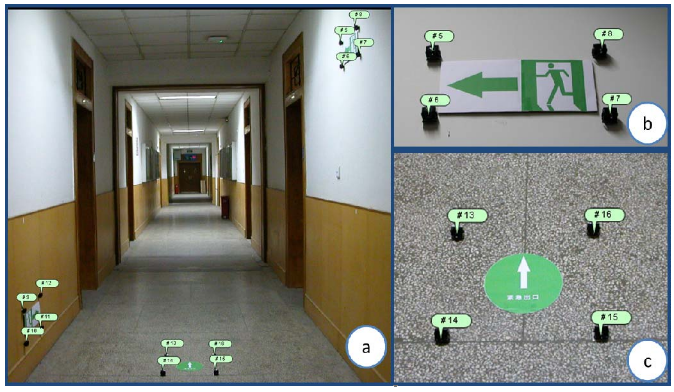


Fig. 1. IR Marker AOIs deployment in normal office real-scene

Figure 1 is the deployment method of IR Marker AOIs under normal office environment. Figure 1.a is the real scene of Xi'an Jiaotong University’s normal office environment which is a corridor inside a building. The IR Marker is deployed at 0.3m from the ground of the left wall, 2.1m from the ground of the right wall and ground floor respectively. Each EXIT design is surrounded with at least four IR Markers for AOIs analysis, as shown in figure 1.b and 1.c. The number in the figure is to record different IR Markers. The infrared sensor on eye tracker can communicate with IR Markers instantly. By coordinate transformation, the different sample persons’ eye movement data can be superimposed together for further analyzed in Fig. 2.

Fig. 2. The different resolution of gaze plot and heat map from head-mounted eye tracker

Figure 2.a is an integrated gaze plot of all the participants' mobile eye tracking data. Fig. 2.b is a reconstructed super-resolution gaze plot of a particular EXIT design (NO1:"Icon"+"Arrow" and "white ground + green content") in the whole scene. Similarly, Fig.2.c is an integrated heat map of all the participants' mobile eye tracking data. Figure 2.d is a reconstructed super-resolution heat map of a particular EXIT design in the whole scene. Here we utilize IR Markers to coordinate the non-uniformed individuals' dynamic eye movement uniformly with a view to quantitatively data analysis and highly improve the eye tracker's scene camera's fixed resolution by scene reconstruction.

B. The setup of the table-mounted eye tracker experiments and results

Based on the study of head-mounted eye tracker's qualitatively mobile data, we can directly found which EXIT sign has an advantage over the others. However the candidate designs' advantages may be very close which need more specific data to comprehensively prove their dominance. In this paper, we present the method of combing mobile and stationary eye tracking techniques to provide not only qualitatively evaluation but also quantitatively evaluations as well. In the stationary eye tracking experiments, we utilize Tobii TX 300[12] table-mounted eye tracker and 3D modeling software SketchUp [13] to simulate the real-scene. Then four types of candidate EXIT designs are placed in the normal office environment model and spacious hall environment model to collect more precise eye movement data. The results are listed in table V and table VI.

TABLE V. QUANTITATIVELY COMPARISON OF THE DIFFERENT EXIT LOCATIONS BY EYE TRACKING METRICS

Eye movement data collect from hall environment				
	TFF(Sec.)	FFD(Sec.)	TFD(Sec.)	FC(Count)
Bottom	2.94	0.39	0.88	2.42
Top	2.15	0.22	0.95	3.75
Eye movement data collect from normal office environment				
	TFF(Sec.)	FFD(Sec.)	TFD(Sec.)	FC(Count)
Ground	0.38	0.21	1.69	6.17
Bottom	2.1	0.27	0.94	3.25
Top	2.17	0.27	0.72	2.92

TABLE VI. QUANTITATIVELY ANALYZE OF EXIT DESIGN BY EYE TRACKING METRICS

	Expected experiment effect	FFD(Sec.)	TFD(Sec.)
 Good	0.21	1.69	6.17
 Average	0.27	0.94	3.25
 Average	0.20	0.87	4.5
 Poor	0.27	0.72	2.92

In table V and VI., TFF stands for Time to First Fixation, FFD stands for First Fixation Duration, TFD stands for Total Fixation Duration and FC stands for Fixation Count. These are four typical eye tracking metrics which used to estimate the test visual objects saliency to the participant. In this group of experiments, 12 sample people with normal or corrected vision attend the test. In order to eliminate the psychological effect of prior knowledge, besides the test materials, the experiment also add in the same amount of "pseudo (dummy)" simulated 3D building images as balancing items. All of the participants are given a list of random visual stimulus using Latin Square method.

Time to First Fixation (TFF) is a representative of the target visual significance, the easier it the shorter the time of arrival that target was found. First Fixation Duration (FFD) on behalf of the speed when object was found after content recognition, the shorter the time is that the higher the efficiency of information transferred. Both Total Fixation Duration (TFD) and total Fixation Counts (FC) are from the unit of time and the count to express the participant's interest distribution on the target area. The longer the TFD is and the more FC is, the more attention the participant distributed his interests on the target object in the whole scene.

IV. THE FINAL OUTCOME OF BUILDING INTERIOR'S EXIT DESIGN THROUGH EYE TRACKING STUDY

Two factors of a wayfinding system of interior building, such as EXIT signage, are very important: noticeability and recognizability. Based on the traditional design experience, we come up with the advanced eye movement research and get the following conclusions:

1) Visual content: According to the experiment, the candidates' designs in table IV from the best to the worst are listed as follows:

(i) "Arrow" +"symbol"
(ii) "Text "+ "arrow"
(iii) "Text" + "arrow"+ "icon"

2) Design Color: Under common daylight source, the "green content + white ground" combination is the best. It is not only visually remarkable high but also not prone to visual fatigue. The visual saliency of "Red content + white ground" is superior to all the others. Owing to the people's "red warning" common knowledge, it gives rise to a certain psychological sense of exclusion. Therefore, such combination is suitable for use in dim lighting to enhance recognizable

3) Design placement location: as expected, ground position gained most attention, while the top position on the wall gain the least. Both in the broad vision of building or narrow vision of building, the ground positon is reflecting an enormous advantage over the other position. But the high cost of ground emergency exit signs and the installation difficulties should be considered in practice, and such design is more suitable for the initial design of new buildings. For those existing buildings, emergency exits can be placed in the wall position. For a broad vision inner building, the top position of the wall is the dominant position, while, for the narrow field of vision, the bottom wall of the dominant position.

V. Conclusion and Future Work

In this paper, we proposed a comparison study of stationary and mobile eye tracking on spatial visual cognition of building interiors by different design of EXITs. In section 1, we first introduce the concept of eye tracking techniques and its application on spatial cognition. The comparisons of stationary and mobile eye tracking techniques are developed to show their advantages and disadvantages respectively. We also analyze the originality of the research in this paper. In section 2 are present the visual elements and design decision of the eye tracking based EXIT experiments. In section 3, the result and discussion of the comparison study of stationary and mobile eye tracking on different design of EXITs are fully developed , and some general spatial visual cognition conclusion are comprehensively explained . In section 4, the final outcomes of the building interior's EXIT design are revealed with support from specific eye tracking data. The research method in the paper is very original and has not been mentioned in other papers of the related fields before. It is the first time to use both mobile eye tracker to get the real scene eye tracking data and the stationary eye tracker to uniformly do the more specific quantitative data analysis which is well worthy data and empirical methodologies can be introduced in wayfinding and space decision making research.

Acknowledgment

The eye tracking equipment and data collection in this paper are partially supported by Xi'an Aite Eyetracking Info Tech Ltd.

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