Actual Way-finding Gaze Behavior in Dynamic Urban Environment: An Eye-tracking Experiment on The North Square of Nanjing Railway Station

Mengyun LI [a], Weijie WANG [b] ,Xuejian Kang[c]

[a,b] *Graduate School of Transportation, Nanjing Tech University, Nanjing, China*
[a] *E-mail: limengyun@njtech.edu.cn*
[b] *E-mail: wangwj@njtech.edu.cn*
[c] *Wonkwang University,Korea E-mail: 1092568030@qq.com*

Abstract: The visual behavior of way-finding in dynamic environment is poorly documented, so the aim of the study was to explore an appropriate way to evaluate the of pedestrian sign system in way-finding processes with head eye-tracking devices and find the problems of pedestrian signs setting in a typical urban space. Field tests were performed in the north square of Nanjing railway station. 5 participants were asked to wear mobile eye tracking glasses and walk from starting point to a specific destination. The main outcomes: first, the pedestrian sign system made participants couldn’ t find the shortest and fastest route to the destination. Second, the most problems were concentrated in some areas that are confusing for participants. Third, the problems of pedestrian signs setting in the confusing areas contained three points. The results of this research can address designers to consider different design strategies to increase the comfort and perceived clear of pedestrian sign system.

Keywords: Eye-tracking, Way-finding, Gaze behavior, Pedestrian sign system

1. INTRODUCTION

Human locomotion is primarily guided and controlled by visual information. Vision is unique in its ability to provide information about near and far environment almost instantaneously: this information is used to regulate locomotion on a local level (step by step basis) and a global level (route planning)(Patla, 1997). Especially in traffic, vision is an important sense for human to perceive surrounding traffic environment. Therefore, eye movement have been studied in car driving, walking and cycling. However, the majority of these studies focused on car driving. The visual behavior of pedestrian in way-finding processes, is poorly documented, even though way-finding is human’s common behavior in unfamiliar environment. Good way-finding requires information processing and decision making, whether in a familiar or an unfamiliar environment(Arthur and Passini, 1992). The pedestrian sign system is designed so that people can walk from one place to another without having to depend on directions from other people(Zheng, 2011), that is, the pedestrian sign system provides pedestrian with valuable information and help them to make right decisions. Therefore, more insight in the visual behavior of pedestrian and the use of pedestrian signs in way-finding processes could be beneficial for comfortable walking environment creating and infrastructural planning.

The development of head eye-tracking devices have provided high-precision human gaze position records and this technology has no longer been limited to indoor and fixed viewing environment(as in reading, marketing, design and advertising studies), it has been applied also in dynamic environment. It is possible to study the relation between gaze and locomotion(Duchowski,2002; Patla and Vickers, 2003; Franchak and Adolph,2010). In recent year, there have been some researches about pedestrian way-finding by using head eye-tracking devices in dynamic environment. Yun Zhang, et al., made a comparison study of stationary and mobile eye tracking on EXITs design in wayfinding system(Yun Zhang, et al 2015). Markus Zank, et al., studied the eye-tracking for locomotion prediction in redirected walking and the results showed that in certain situations, eye tracking allows an earlier prediction compared approaches currently used for redirected walking.(Markus Zank, et al.2016). Nevertheless, a lack of realism can be found in the majority of wy-finding studies on pedestrian eye movements: many of these have been based on tests conducted in controlled in-door environment , or have resorted to videos recorded in real environment or to simulation. Furthermore, almost no way-finding study focused on pedestrian sign system by using head eye-tracking device in dynamic environment.

In this study, pedestrian sign system was focused since it is the key to convey information to pedestrians. The effective setting of pedestrian signs could greatly avoid pedestrians lost. So the first aim of the study is to find a appropriate way to evaluate the of pedestrian sign system in way-finding processes with head eye-tracking devices. This study carried on an experiment allowing a quantitative study of actual way-finding gaze behavior in real urban environment. The second aim of the study is to find the problems of pedestrian signs setting in a typical urban space and these problems will be summarized to provide some improvement opinions for future pedestrian sign system design.

2. METHODS

In order to study way-finding gaze behavior in dynamic environment, we took the setting of pedestrian sign in typical urban space as a breakthrough and made an experiment. We chose the north square of Nanjing railway station as experiment site. In the experiment, the participants wearing eye-tracking glasses were asked to start from the starting point to find a specified destination. The eye tracking device recorded data throughout the whole way-finding processes. After the performance, participants completed a survey about the way-finding experience. The data were analyzed using the BeGaze 3.5 software. At last we summarized the problems of pedestrian signs setting.

2.1 Participants

The participants(20-25 years of age) took part in the study and signed the informed consent. Of five Participants, three were graduate students of Nanjing Tech University, one was undergraduate of Nanjing University of finance and economics ,and one was graduate student of Hohai University. In order to study a real way-finding condition, all participants were the first time to come to the experimental site and unfamiliar with the experiment site’ s routes layout. One participants were left out since his Eye-Tracking Ratio (percentage of time eye movement was actually measured) was less than 80%(Vansteenkisted et al., 2014). The four remained participants had normal or corrected to normal vision.

2.2 Experimental Site

Experimental site were selected in the north square of Nanjing railway station. Nanjing Railway Station, located in No. 111, Longpan Rd, Xuanwu District, Nanjing, is one of the railway junctions in China. It is a first-class Railway Station of China and ranks among top 10 Chinese Railway stations. Nanjing Railway Station covers an area of 1.2 million square meters with two station buildings, namely the South and the North station building. Each station building has its own square, called the south square and north square.

The north square(see Figure 1.), a typical urban space, which is only for pedestrian and in front of the North station building. The public facilities especially pedestrian sign system of the north square are not very perfect which often make tourists feel lost since it is a new square and opening to public just for two and a half years and it can’t be connected with the south square. The north square calls for a deeper study of walking behavior, in order to make the infrastructural investments effective and the walking environment more comfortable.

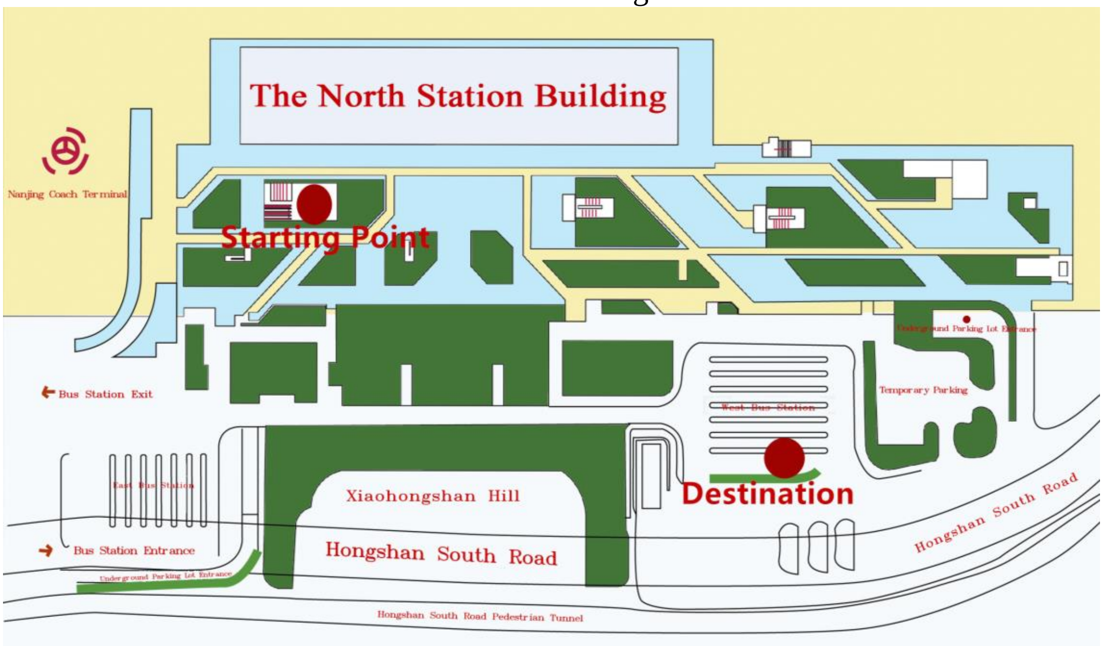


Figure 1. The sketch map of the north square

2.2 Apparatus

Eye movements and gaze location were recorded using the SMI Eye Tracking Glasses 2 Wireless(SMI ETG) which is a mobile eye tracking device with a 60Hz/120Hz binocular sampling rate(see Figure 2.). It captures a user’s eye movements with high definition scene camera and special eye tracking technology. The SMI ETG is worn as a normal pair of glasses. After connecting it to an Recording Device(Samsung Galaxy Note4 SmartPhone; 176g), it is powered up and ready for use. The SMI ETG is initialized simply by having the wearer briefly fixate on one point in the environment. Two small cameras on the bottom rim of the glasses capture the eye movements of the wearer and map the wearer’s gaze point into a scene video. The system was calibrated using one-point or three-point and has an accuracy of 0.5°.

Figure 2. Participant wearing the SMI Eye Tracking Glasses

2.3 Procedure

After giving informed consent, the participant was asked to put on the eye-tracking glasses. A three-points calibration were performed indoors and the participant was then asked to follow the test leader to the the starting point (see Figure 1. intercity railway north exit which on basement level one). After pressing the start recording key on the Recording Device screen, participants started to search for the destination(see Figure 1. 510 bus station) according to the requirements. A experimenter followed the participant without any communication during the whole way-finding process. When the participant arrived the destination, the experimenter help the participant to press the stop key and the data were saved.

After the performance, participants completed a survey about the way-finding experience. They have been asked to provide information regarding their perception of way-finding quality, the perceived visual signs information, by what were their way-finding plans, which location they felt more difficult to find the way, why they felt lost, and other personal information- e.g. Regarding their senses of direction. At last, each participant was asked to pointed out two areas made him or her feel lost.These two areas are named confusing area and abbreviated as CA.

2.4 Data analysis

The data were analyzed using the BeGaze 3.5 software. For each trial, way-finding routes and total time was recorded by the device. The video data with overlay gaze cursor were exported from BeGaze. The analysis was divided into overall evaluation and individual evaluation.

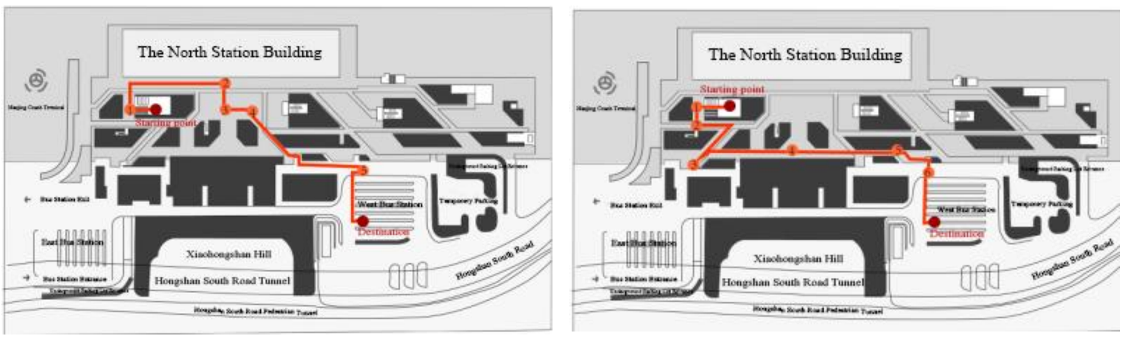
Overall evaluation's indicators were the participants' way-finding routes and the participants' walking time.

Individual gaze behavior was evaluated by key performance indicators(KPI) to specific areas of interest(AOI). AOIs are the pedestrian signs and the other areas participants focused on. Five or four AOIs were chosen from each participant's two confusing areas(CA). The needed KPI includes Sequence, Dwell time, Revisits, Fixation count and two extra indicators: Confusing area(CA's number) and Type of AOI(pedestrian signs or other). Sequence is the order of gaze hits into the AOIs based on the Entry Time (Average), lowest Entry Time = first Sequence. Sequence can reflects the internal logic of gaze behavior. Dwell time(ms) is the sum of all fixations and saccades within an AOI for the selected participant which reflects the attractiveness of the AOI to the participants or the degree of Attention and demand for AOI. The significance of Dwell time is that it can measure the effectiveness and rationality of the pedestrian sign setting as an AOI. Fixation count is the number of all fixations for the selected participant which reflects the degree of attention for AOI. The significance of fixation count is that it can measure the participants' demand for the pedestrian sign as an AOI. Revisits is average revisits which equals the number of glances divided by the selected participant with at least one visit minus one(glances equals the increments the counter each time a fixation hits the AOI if not hit before). Revisits reflects the participant's certainty of the information from the AOI. E.g. If a participant can not get clear information from a pedestrian sign quickly, the participant's may see the sign over and over again.

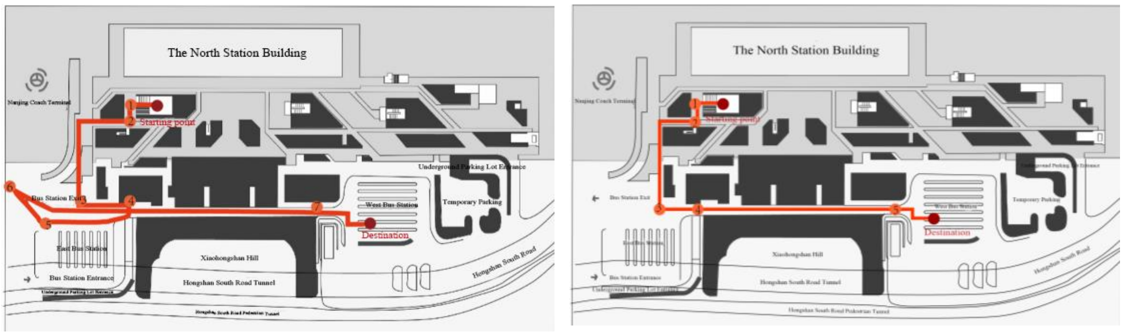
3. RESULTS AND DISCUSSIONS

3.1 Overall Evaluation

Four participants' way-finding routes were recorded and lined out on the sketch map of the north square (see Figure 3.). Under the normal circumstances, the shortest walking distance from starting point to destination is about 450 meters but none of the participants chose the shortest route. The sequence numbers represent some special positions including choice points, directional changes points, the joint area of different functions and the confusing area (CA) throughout the whole way-finding processes.



(a) Participant A (b) Participant B



(c) Participant C (d) Participant D

Figure 3. The participants' walking routes.

By analyzing Figure 3. (a),(b),(c) and (d), it is clearly results that four participants chose totally different walking routes. Participant A made a path selecting decision at the NO.1 point which was different from the other three participants. The video and audio data showed that participant A went up to someone and asked directions.

Comparing Figure 3. (b), (c) and (d), participant B made a different path selecting decision with participant C and participant D at the No.2 point and turned back at the No.3 point. It is important to point out that the No.3 point was located in the entrance of the east bus station which is another bus station of the north square.

Comparing Figure 3. (c) with (d), participant C turned back at the No.4 point and then he walked about 50 meters to No.6 point. According to the video and audio data, that participant A went up to someone and asked directions at No.6 point.

From the survey about the way-finding experience, each participant pointed out two confusing area(CA). Duplicate areas of eight areas merged into five unique areas and then numbered these areas sequentially. For an overview of the participants' walking time information see Table 1.

Table 1. The participants' walking time information

Participant	Total time	Time of confusing area		
		CA's number	Time	Time/Total time%
Participant A	6min18s	①	1min7s	18%
		⑤	1min5s	17%
Participant B	5min53s	①	33s	9%
		②-③	34s	10%
Participant C	7min57s	①	38s	8%
		④	2min29s	32%
Participant D	7min41s	①	1min2s	12%
		④	41s	9%

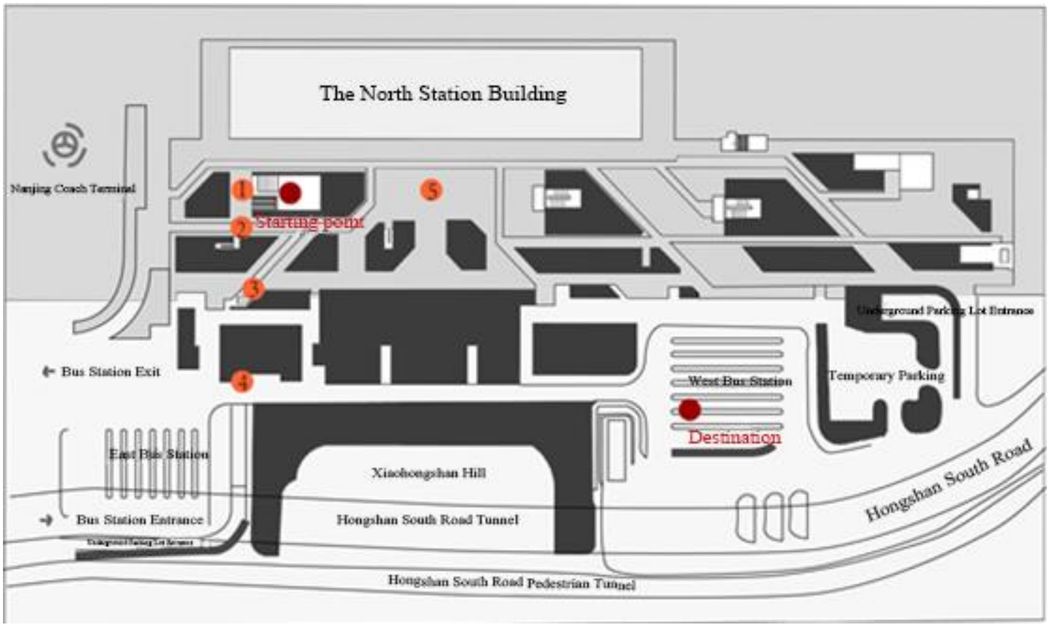


Figure 4. The location of CA point

Figure 4. and Table 1 show that participants chose different routes and spent different time to arrive at the destination. It can be inferred that the setting problem of pedestrian signs result in pedestrians' confusion that they can not get the accurate information of direction. In this situation, pedestrians relied on the limited visual information and their own sense of direction to select path which was easily to make mistakes or spend more time than it actually needs.

From Table 1, four participants spent long time on the areas of getting lost, which accounted for 35%, 19%, 40% and 21% of the total time. Comparing the amount of time that participants spent on the same CA, it is found that the time of participant A and D spent are two times participant B and C spent at the No.1 CA point and the time of participant C spent are four times participants D spent at the No.4 CA point. It comes to conclusion that ①The overall design of the pedestrian sign system made participants couldn't find the shortest and fastest route to the destination. ②The most problems were concentrated in some areas that are confusing for participants.

Analysis of four participants individual eye tracking data in the confusing areas points are below which made a deeper study to find out the problem of the pedestrian sign arrangement.

3.2 Individual Evaluation

3.2.1 Participant A

Table 2 shows the participant A's KPI data. The sequence of participant A's AOI is AOI002, AOI004, AOI001, AOI003, AOI005. The first AOI is AOI002, Dwell time is 182.3ms, Fixation count is 1, Revisits is 0. It can be inferred that AOI002 attracted participant A's attention first but the dwell time is short which means AOI002 didn't attract persistent attention, so the pedestrian sign in AOI002 wasn't necessary for participant A. The video data shows that the AOI001(the map of north square) didn't attracted participant A' attention when participant A took escalator to the square from basement level one. In addition, AOI001's Fixation count is 2 and Revisits is 1. It can be inferred that the map of north square was unattractive and couldn’t convey information accurately. Dwell time of participant A’s five AOIs are 514.3ms, 182.4ms, 165.8ms, 1062.2ms, and 564.0ms. The Dwell time of AOI004 is longest which reflects the location of AOI004 was the most attractive to the participant A's attention in the way-finding process. The Fixation count of AOI004 is 6 which is most among the five AOIs but the Revisits is 2. It means that participant A paid much attention to AOI004 but couldn’t make sure about some information of AOI004. The field survey found that AOI004’s location didn’t set any pedestrian sign. Combining the data and the field survey results, it Indicates that the degree of need for pedestrian signs for AOI004 was very high but it was actually a lack of appropriate facilities in AOI004. Similarly, AOI003, AOI005 did not set any pedestrian sign, but participant A was most concerned about these two areas. Dwell time of AOI005 is 564.0ms, Fixation count is 2 and Revisits is 1 which reflects that the location of these two areas should be equipped with appropriate pedestrian signs.

In summary, the problems of pedestrian sign system on pedestrian A’s route are: ①The pedestrian sign setting of the important position (AOI001) was not enough conspicuous.②There was a lack of pedestrian sign in some confusing positions (AOI003, AOI004, AOI005).

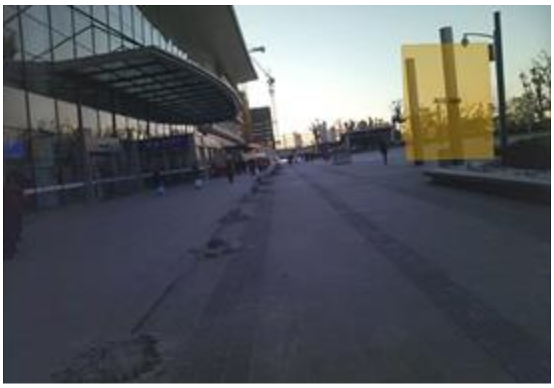
Table 2. Participant A’s KPI data

	AOI001	AOI002	AOI003	AOI004	AOI005
Sequence	3	1	4	2	5
Dwell time	514.3ms	182.4ms	165.8ms	1062.2ms	564.0ms
Revisits	1	0	0	2	1
Fixation count	2	1	1	6	2
Confusing area(CA)	①	①	①	⑤	⑤
Type of AOI	Sign	Sign	Other	Other	Other


(AOI001)


(AOI002)


(AOI003)


(AOI004)

(AOI005)

Figure 5. Participant A's AOI

AOI 001	
Sequence	3
Entry time	185939.7 ms
Dwell time	514.3 ms (0.4 %)
Hit ratio	1/1 (100.0 %)
Revisits	1.0
Revisitors	1/1
Average fixation	257.1 ms
First fixation	381.6 ms
Fixation count	2.0

（AOI001）

AOI 002	
Sequence	1
Entry time	119324.2 ms
Dwell time	182.4 ms (0.1 %)
Hit ratio	1/1 (100.0 %)
Revisits	0.0
Revisitors	0/1
Average fixation	182.4 ms
First fixation	182.4 ms
Fixation count	1.0

（AOI002）

AOI 003	
Sequence	4
Entry time	189424.8 ms
Dwell time	165.8 ms (0.1 %)
Hit ratio	1/1 (100.0 %)
Revisits	0.0
Revisitors	0/1
Average fixation	165.8 ms
First fixation	165.8 ms
Fixation count	1.0

（AOI003）

AOI 004	
Sequence	2
Entry time	140450.5 ms
Dwell time	1062.2 ms (0.8 %)
Hit ratio	1/1 (100.0 %)
Revisits	2.0
Revisitors	1/1
Average fixation	149.4 ms
First fixation	116.3 ms
Fixation count	6.0

（AOI004）

AOI 005	
Sequence	5
Entry time	202220.2 ms
Dwell time	564.0 ms (0.4 %)
Hit ratio	1/1 (100.0 %)
Revisits	1.0
Revisitors	1/1
Average fixation	248.8 ms
First fixation	315.1 ms
Fixation count	2.0

（AOI005）

Figure 6. Participant A's KPI of AOI

3.2.2 Participant B

Table 3 shows the participant B’s KPI data. The sequence of participant B’s AOI is AOI001, AOI002, AOI004. AOI003 and AOI005 are not appear in the sequence, indicating that participant B did not pay attention to AOI003 and AOI005 which were pedestrian sign, that is, these two settings did not attract the attention of the participant A. Thereby, it indicated that the location of the two pedestrian signs were not appropriate. The Dwell time of AOI001, AOI002 and AOI004 are 8015.8ms, 398.1ms, 249.0ms. The fixation count of AOI001, AOI002 and AOI004 are25, 3, 2. The Revisits of AOI001, AOI002 and AOI004 are 2, 2, and 1. The Dwell time and the Fixation count of AOI001 are much more than AOI002 and AOI004, which means the information of AOI001 attracted participant B most and the information of the pedestrian sign in AOI001 was valuable for participant B to distinguish the direction. However, the Revisits of AOI001 were also more than usual, which means the pedestrian sign in AOI001 couldn’t convey information accurately. There were Revisits in very short Dwell time in AOI002 and AOI004, which reflects participant B re-read AOI002 and AOI004 to confirm the information. It indicates participant B need pedestrian sign in these two areas, but there was no pedestrian signs in AOI004.

In summary, the problems of pedestrian sign system on pedestrian B's route are: ①The pedestrian signs setting of the important position (AOI003,AOI005) was not conspicuous enough .②The information of the pedestrian signs was not clear enough. ③There was a lack of pedestrian sign in some confusing positions (AOI004).

Table 3. Participant B's KPI data

	AOI001	AOI002	AOI003	AOI004	AOI005
Sequence	1	2	-	3	-
Dwell time	8015.8ms	398.1ms	0.0ms	249.0ms	0.0ms
Revisits	2	2	-	1	-
Fixation count	25	3	0	2	0
Confusing area(CA)	①	②-③	①	①	②-③
Type of AOI	Sign	Sign	Sign	Other	Sign

3.2.3 Participant C

Table 4 shows the participant C's KPI data and that there is no data about AOI002, AOI003 and AOI004, AOI001 was the only area participant C paid attention to. It can be inferred that participant C didn't noticed the pedestrian signs in AOI002, AOI003 and AOI004. According to the data of AOI001, Dwell time of participant C is 8845.3ms and Fixation count is 42, which reflected the high degree of attentiveness of AOI001. Revisits is 4 times, which reflects the process of confirming information and indicates that the information provided by the AOI001 is not clear enough.

In summary, the problems of pedestrian sign system on pedestrian C' s route are: ①The pedestrian signs setting of the important position (AOI002, AOI003, AOI004) was not conspicuous enough .②The information of the pedestrian signs was not clear enough.

Table 4. Participant C's KPI data

	AOI001	AOI002	AOI003	AOI004
Sequence	1	-	-	-
Dwell time	8845.3ms	0.0ms	0.0ms	0.0ms
Revisits	4	-	-	-
Fixation count	42	0	0	0
Confusing area(CA)	①	①	①	④
Type of AOI	Sign	Sign	Sign	Sign

3.2.4 Participant D

Table 5 shows the participant C's KPI data and there is no data about AOI002, and AOI004. It can be inferred that participant C didn't noticed the pedestrian signs in AOI002 and AOI004. According to the data of AOI001, Dwell time of participant C is 20910.3ms and Fixation count is 82, which reflected the high degree of attentiveness of AOI001. Revisits is 5 times, which reflects the process of confirming information and indicates that the information provided by the AOI001 is not clear enough.

In summary, the problems of pedestrian sign system on pedestrian C's route are: ①The pedestrian signs setting of the important position (AOI002, AOI004) was not conspicuous enough .②The information of the pedestrian signs was not clear enough.

Table 5. Participant D's KPI data

	AOI001	AOI002	AOI003	AOI004
Sequence	1	-	2	-
Dwell time	20910.3ms	0.0ms	1576.3ms	0.0ms
Revisits	5	-	0	-
Fixation count	82	0	1	0
Confusing area(CA)	①	①	①	④
Type of AOI	Sign	Sign	Sign	Sign

Table6. The problems of pedestrian signs setting

Participant's Route	Problems
Participant A's route	①The pedestrian signs setting of the important position was not conspicuous enough；(AOI001) ②There was a lack of pedestrian sign in some confusing positions；(AOI003, AOI004, AOI005)
Participant B's route	①The pedestrian signs setting of the important position was not conspicuous enough;(AOI003,AOI005) ②The information of the pedestrian signs was not clear enough; ③There was a lack of pedestrian sign in some confusing positions (AOI004).
Participant C's route	①The pedestrian signs setting of the important position was not conspicuous enough；(AOI002, AOI003, AOI004) ②The information of the pedestrian signs was not clear enough.
Participant D's route	①The pedestrian signs setting of the important position was not conspicuous enough;(AOI002, AOI004) ②The information of the pedestrian signs was not clear enough.

According to eye movement data analysis of the four participants, it can come to the conclusion that the problems of pedestrian signs setting(see Table 6).

The problems of pedestrian signs setting in the confusing areas are that:①The pedestrian signs setting of the important position was not conspicuous enough; ②The information of the pedestrian signs was not clear enough. ③There was a lack of pedestrian sign in some confusing positions.

The general aim of this study was to find a way to describe pedestrians' visual behavior during way-finding processes and the problems of pedestrian signs setting in a typical urban space. The study of pedestrian eye movements can be a tool to understand visual behavior and to investigate which strategies are adopted in way-finding. Various elements of the urban space environment can be perceived by the pedestrian as attention-requiring, and it seems fair to assume that pedestrian sign system is the key element effecting efficiency of way-finding since it as valuable information for pedestrian.

The study is an attempt using head eye tracking device to study the visual behavior for pedestrian sign in way-finding processes. The participants wearing eye-tracking glasses were asked to start from the starting point to find the specified destination. The visual behavior data recorded by device told us that what were the participants thoughts during way-finding processes, such as where they wanted to get direction information, the effectiveness of a specific pedestrian sign and so on.

An important limitation of current study, is the low number of participants. As future developments of the research, the number of participants will be extended, in order to provide a more consistent statistical analysis.

A second limitation of current study is that four participants chose totally different routs so that it is difficult to compare four participants' data. It is known that individual data can not represent the public so each of the four participants encountered the pedestrian sign problems that may be merely case-specific and non-universal.

4. CONCLUSIONS

The quantitative study of pedestrian gaze behavior was performed by using an eye movement tracking device. 5 field tests were performed in the urban center of Bologna, Italy. From gaze data recorded by the mobile eye detector, we analyzed which visual information were detected. By the overall evaluation and individual evaluation

There are the main outcomes: first, the overall design of the pedestrian sign system made participants couldn't find the shortest and fastest route to the destination. Second, the most problems were concentrated in some areas that are confusing for participants. Third, the problems of pedestrian signs setting in the confusing areas are that:①The pedestrian signs setting of the important position was not conspicuous enough; ②The information of the pedestrian signs was not clear enough. ③There was a lack of pedestrian sign in some confusing positions.

The results of this research can address designers to consider different design strategies to increase the comfort and perceived clear of pedestrian sign system.

5. AKNOWLEDGMENT

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REFERENCES

Alessandra, M., Silvia B., Federico R. (2016) Cyclist gaze behavior in urban space: An eye-tracking experiment on the bicycle network of Bologna. World Conference on Transport Research Society. Published by Elsevier Ltd

Arthur, P., Passini, R. (1992) Wayfinding: People, Signs, and Architecture. McGraw-Hill Books, New York.

Duchowski, A.T. (2002) A breadth-first survey of eye-tracking applications. Behav. Res. Methods Instrum. Comput. 34, 455‑470.

Duchowski, A. T. (2007) Eye tracking methodology: Theory and Practice (2nd ed., p. 328). London: springer.

Franchak, J.M., Adolph, K.E. (2010) Visually guided navigation: head-mounted eye-tracking of natural locomotion in children and adults. Vision Res. 50,2766‑2774.

Itti, L.; Koch, C. (2001) Computational modelling of visual attention. Nat. Rev. Neurosci. 2,194‑203.

Land, M.F. (1992) Predictable eye head coordination during driving. Nature 359,318‑320.

Land, M.F. (2009) Vision, eye movements: and natural behavior. Vis. Neurosci. 26,51‑62.

Patla, A. E. (1997) Understanding the roles of vision in the control of human locomotion. Gait and Posture, 5(1), 54‑69.

Patla, A.E., Vickers, J.N. (2003) How far ahead do we look when required to step on specific locations in the travel path during locomotion? Exp. Brain Res.148,133‑138.

Vansteenkiste, P., Cardon, G., D'Hondt, E., Philippaerts, R., Lenoir, M. (2013) The visual control of bicycle steering: the effects of speed and path width. Accid. Anal. Prev. 51, 222‑227.

Vansteenkiste, P., Zeuwts, L., Cardon, G., Philippaerts, R., Lenoir, M. (2014) The implications of low quality bicycle paths on gaze behavior of cyclists: a field test. Transp. Res. Part F: Traffic Psychol. Behav. 23, 81‑87.

Wiener, J.M., Hölscher, C., Büchner, S., Konieczny, L. (2012) Gaze behaviour during space perception and spatial decision making. Psychol. Res. 76, 713‑729.

Yun Zhang, et al. (2015) A comparison study of stationary and mobile eye tracking on EXITs design in a wayfinding system. APSIPA Annual Summit and Conference, 16-19 December 2015

Zheng, Mc. (2011) Time Constraints in Emergencies Affecting the Use of Information Signs in Wayfinding Behavior. Asia Pacific International Conference on Environment-Behaviour Studies, Salamis Bay Conti Resort Hotel, Famagusta, North Cyprus, 7-9 December 2011.