How the Alignment Pattern and Route Direction Affect the Design of the Bus Stop Board: An Eye Movement Experimental Research

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Abstract. An eye movement study was conducted to study the visual factors which influencing the searching efficiency of bus stop board. 31 ordinary adults were measured to investigate the effects of the alignment patterns, the positions of the arrow indicating bus route direction on the searching efficiency of the different sexual passengers at different age stage by Eye-tracking. The eye movement experiment took the bus stop names as material, set simulated bus route, and made series of bus stop boards with different color combinations and graphic designs. The result shows that the difference in search time and fixation times between the positions of the direction arrow and the alignment patterns of the bus name list is significant. When the arrow was below of the bus stop name list, it cost much less time for distribute alignment bus stop boards than for top alignment ones in searching destination bus stop; and when the bus stop name list was in distribute alignment, those bus stop boards which the direction arrow was below the bus stop name list had a significant advantage over those that the arrow was above in searching time and fixation times. As a conclusion, the obtained results could be a reference for design the bus stop board.

Keywords: Bus stop board · Alignment patterns · Arrow position · Searching efficiency · Fixation time · Eye-tracking

1 Introduction

The bus stop boards are a kind of public information signs set at bus stops, which generally are formed by graphical symbols, text and colors, to provide passengers with travel information [1]. Bus stop boards are important guidance tools for passengers travelling by bus. Bus stop boards with low visual search efficiency are easily lead to stranded passengers and congestion at the bus stop. Many ergonomics researchers focus on the visual cognition characteristics of the bus stop boards to make the design conformed to passengers' visual cognitive processing habits. Bus stop boards with good design will help passengers travel fast and convenient.

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In previous studies, data showed that there were many problems on the bus stop boards' visual design. For example, it was difficult for passengers to read the information on the bus stop boards which installed in various cities, the fonts' size were too small, the colors were dull and dreadfully alike, the information were incomplete [1]. As there were no indications about the travel directions and the approaching stops, those also caused inconvenience for passengers to confirm the current stops [2].

Xie et al. [2] found that "using response time and accuracy in searching bus stop boards as indicators, the visual search performance on recognizing the current stop will be improved a lot with adding highlighted display", and "the performance of highlighted arrow and color is much better than that of using bigger font size". Chen [3] found some existing problems on bus stop signs "can't identify one/two way of bus route", "lack the position information of the stop at opposite side, forward or backward", "lack the route diagrams on relative transferring bus routes", and "the approximate orientation of bus running route in the city". Zheng Zhe Chen also put forward several suggestions on designing the bus stop signs. Zheng [4] gave several advices and new concepts on fonts, diagrams and graphical designing methods which based on the psychology and visual cognitive process theories. Ding et al. [5] conducted a case investigation on SHANGHAI bus stop boards from the following aspects: color scheme, information completeness, beautiful appearance, convenience, English translation, night illumination and the need of disabled groups. Ding et al. [5] also suggested several improvement aspects on the design.

The above researches collected some existing questions on bus stop boards' design via various methods including questionnaire method, behavior experiment method and theoretical analysis method. But they haven't studied into the visual cognitive process in bus stop boards design.

With the rapid technical development, eye movement theory and tracer technique are widely used in the road traffic research on various design and setting fields, including the design of the cab console panel, the design of vehicle vision, the design of vehicle color (e.g. vehicle body color, cab color, and signal lamp color), the design of road line, the design of road crossing, the design of tunnel entrance and exit, the design and setting of road traffic facilities, signs and markings, the design of street trees and isolation belt plants. The design of bus stop board is the focal point of this paper, which is similar with the design of road traffic facilities, signs and markings. In order to improve the design and setting of road traffic facilities, signs and markings, some researchers study the eye movement features, visual characteristic, and their relationships [6, 7]. As eye movement can reflect the visual information searching mode effectively, it has more important value in explaining the mental mechanism of visual cognitive process. Relative research findings have been widely used in cognitive studies on website, advertisement and graphics.

Visual search is a complicated cognitive process, normally, it focuses on find out the specific stimulation in a stimulus context, which is performance oriented. From the explicit behavior, the visual search gained the outside stimulus information and fulfilled the information processing by a series of saccades and fixations [8]. Lots of factors influence the efficiency of visual search, in which the physical properties of stimulus is one of the most important factors. As early as in 2006, some researchers studied the saccade mechanism of visual search using eye tracer technique. Ding (2007) eye movement study found that there were obvious asymmetry features of left eye and right eye movements when participants did graphic visual search. The main asymmetry features are: the average fixation time of the left side view was significantly longer than that of the right side view; the search saccade distance of the left side view was shorter than that of the right side view; the searching saccade speed of the left side view was slower than the right side view; the beat frequency of the left side view was significantly more than that of the right side view. For search strategy, the average fixation duration of vertical search was significantly longer than that of horizontal search [9].

Many studies were conducted on the information display methods to improve the speed and quality of the visual interfaces information communication by designers and researchers. Hu et al. found that using highlighted display methods (e.g. color, flashing, title) can significantly enhance the users' visual search efficiency. An appropriate color code may effectively reduce the visual search time. Their study indicated the highlighted display might influence user' searching strategy: when using highlighted display interface, participants can collect limited resources together and reduce useless search to enhance the search efficiency. On the contrary, when using non-highlighted display interface, participants mainly use sequential search strategy, they are unable to collect limited resources together, so the invalid searches are increasing and the search efficiency is poor [10]. Ge (2009) indicated there were some differences in the cognitive processing and checking methods on road information structure. The main difference was that the eye movements vary by participants. A symmetric road information structure could improve the users' efficiency on reading road traffic signs. Eye movement data indicated that the fixation points and retrace time were reduce a lot, and the gazing time was significantly shorter when using symmetric structures. So the symmetric structure for road traffic signs can improve the visual search efficiency obviously. A symmetrical structure information effect does exist [11].

On the point of search strategy, some researchers found that when participants employed directive search strategy, the number of fixation was significantly lower, the saccade trajectory length was shorter, and the fixation time was much less, in result, the search efficiency was better. While when participants employed sequential search strategy, the number of fixation was much more, the saccade trajectory length was longer, and the fixation time was much more, in result, the search efficiency was worse. The research indicated visual interface structure, label and the project semantic features might influence the participants search strategy and reduce the number of fixation to improve search efficiency [12]. In this paper, we try to use the eye movement tracer method to study the influence of various highlighted visual interfaces on the bus stop boards' visual search efficiency to collect experimental data for improving the bus stop boards' design.

2 Method

2.1 Experiment Design

Within-subject and between-subject crossed four factors design was conducted to investigate the effects of the alignment patterns, the positions of the arrow indicating bus route direction on the searching efficiency of the different sexual passengers at different age stage. A 2 (the positions of the arrow indicating bus route direction: above vs. below the bus stop name list) × 2 (the alignment patterns of the bus stop name list: top alignment or distribute alignment) within-subject factorial design with two additional control condition were used in this experiment. The additional independent variables were: age (young vs. older) and gender (male and female). In this experiment, the search time and fixation times were measured by eye-tracking to assess and compare which type of bus stop board design is better.

2.2 Participants

Thirty-one ordinary adults from 20 to 66 years old (14 male and 17 female, mean age = 40.42, standard deviation of age = 15.83) were recruited and paid to participate in the experiment. All subjects were divided into two groups, one group was young from 20 to 44 (9 male and 8 female, mean age = 27.18, standard deviation of age = 5.34); the other group was senior from 45 to 66(8 males and 6 female, mean age = 56.50, standard deviation of age = 5.96). All had normal or corrected-to-normal visual acuities and healthy physical conditions, without ophthalmic diseases. They did not have any history of neurological and mental diseases. And the participants were divided into two groups, one group were younger group which included nine male and eight female, and the other group were senior group which included eight male and six female.

2.3 Stimulus

The eye movement experiment took the bus stop names as material, set simulated bus route, and made series of bus stop boards with different color combinations and graphic designs. From Beijing city bus station name library selects the bus station name and form 11 virtual circuit made of green bottom mispronounced character matching bus stop pictures, of which each bus stop containing 46 bus station. One of them was as the practice trial. Each route has 4 target station to search which represent four experimental level and the position effect of the target stations were balanced. 40 search trials were randomly divided into 7 groups, each group included of 4–8 trials. The 4 target search trials of the same line were evenly distributed in each group. The 4 bus stops of the same line were not adjacent for each other. Each experimental level has designed 10 standard trials to emphatically analyze which there were 20 stations between the target station and the current station, and the rest are filled trial. The standard trial of each experiment level was evenly distributed in each experimental group, and their locations were not in the first or in the last of each experimental group. The positions of the standard trials in each experimental group were pseudo randomly arranged.

As generating the virtual circuit bus stop, the station name is selected to avoid the special place (such as Zhongnanhai, Badaling station) and the very familiar place (such as Sanyuan Bridge). And the station names was arranged by pseudo random and the station names with different words (including 2 words, 3 words, 4 words, 5, 6 words, 7 words) was evenly distributed throughout the virtual circuit. The station order was arranged by considering the geographical location to avoid a clear violation of the common sense (Fig. 1).

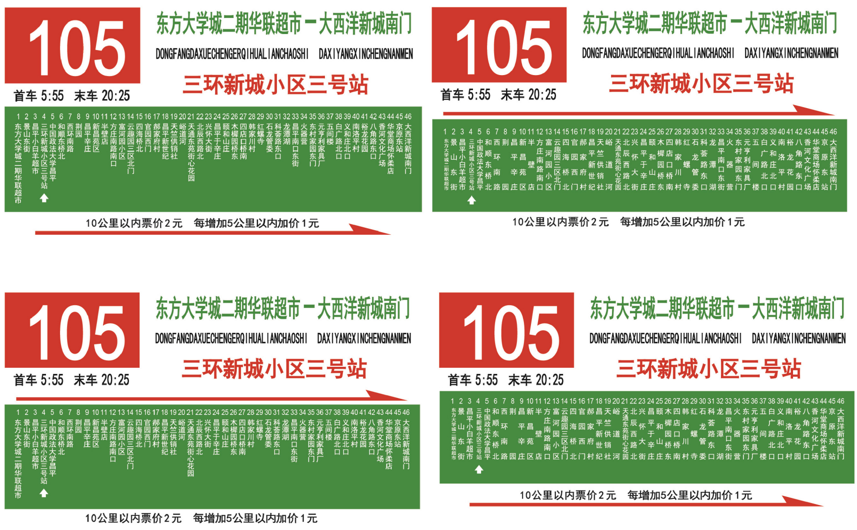

Fig. 1. The stimulus example

The locations of the initial stations were distributed random. The station name with 2 words was not as the initial station and terminal station. Target stations were selected by taking into account the word number, the location and other factors. The terminal station are not the target station. The image resolution was 1284 × 812 and the image example was as follow:

2.4 Apparatus

Experiments were conducted in a quiet and bright environment which simulated outdoors condition. It was installed in the laboratory in the Institute of Human Factors and Ergonomics in China National Institute of Standardization. The eye-tracker was SMI iView X RED made by SMI Corporation and its sampling rate is 60 Hz. And DELL Latitude D620 was as the experimental host with 2116 Hz core frequency, 2G memory card, independent graphics card. The host was connected to two monitors, one monitor was 19 inch display which was presented stimuli for subjects and subjects responded through the mouse and keyboard, while the eye tracker below the display recorded the subjects' eye movement data; the other display device showed the subjects' eye movement for the objects during the experimental process. And the resolutions of all the display terminals were 1280 × 1024 and their refresh rates were 60 Hz. The experimental programs was automatically generated by SMI Center Experiment.

2.5 Procedures

The eye movement experiment on the design of bus stop board was conducted in the Institute of Human Factors and Ergonomics lab in China National Institute of Standardization. After arriving at the laboratory, participants signed the informed consent and completed a general survey about their demographic information. The participants were asked to sit into the simulator to get ready for the test. After that, the participants were required to complete the visual search task by simulating reading the bus stop boards. The experiment are vertically arranged in the height adjustable special experimental table. Before the experiment, the height of the table and display position were adjusted to make the participants' eyes and display center on a line. The viewing distance is about 60–70 cm, and the head tracking range is 40*40 cm. Before viewing the bus stop board, an eye movement calibration was done to ensure data precisely. Then, participants read experimental instruction and did some exercises to ensure participants understand the instruction and conduct the visual search task correctly. If participants don't know the experimental process, then let him/her do practice again. After practice, the experimenter would validate simply the search strategy which the subject used, but do not make any judgments and tips. Then, they entered the formal experiment. During viewing the bus stop boards, the participants' eye movement data were recorded. There was three to five minutes resting between each group. After viewing all the pictures, the participants were required to tell which search strategy he/she used. Each participant spent about one hour finishing the experiment. The searching time and fixation times were recorded by SMI eye-tracker as efficiency indexes when the participants reading different designed bus stop boards. The experimental instruction was as follows:

> "You will see a series of bus stop pictures. Before each picture presenting, it will show you a few words in the center of the screen, and that is the station where you are going to. When you memory the target station, please press the spacebar. Then, please find out the target station and count the number of the interval of stations between the target station and the current station on the next bus stop. The number does not contain the current station, also does not include the target station, and it only include the stations in the middle. After determining the number of stations, please input the number through the keyboard, then press the space bar to enter the next trial. When you input the number of stations, the screen will not have any presentation, you should input it as usual. The whole process is not reversible, it means that you can't look back a picture or text, so please ensure that each your operation is accurate. If you are ready to begin the experiment, please switch off the mobile phone or set it at the quiet mode."

2.6 Data Analysis

According to the experimental design, the data of standard trials were analyzed through the BeGaze software. The standard trial was divided three regions of interest which were current station, target station and the middle region between the two stations. The time that first enter the target station was as the search time, and the fixation times in the middle regions were as the fixation times. They were as indexes for further data analysis. According to the behavior data and the search strategy that subjects used, the first fixation time data were corrected, and the trials with incorrect behavior data were excluded. The eye movement data of all standard trials were exported from the SMI BeGaze software and analyzed by IBM SPSS 20 Statistics software (IBM-SPSS Inc. Chicago, IL). The repeated-measure ANOVA was applied to analysis the data of searching time and fixation times.

3 Results

3.1 The Means of Search Time and Fixation Times for Each Condition

Tracking test was conducted to compare the effect of the Bus Stop Board's Design with different alignment patterns and route direction. The search time and fixation times data were analyzed. A 2 × 2 × 2 × 2 mixed-measure ANOVA was conducted to evaluate age group(above 40 years old and below 40 years old), gender group(male and female), alignment patterns (top alignment or distribute alignment) and route direction(above the bus stop names and below the bus stop names). Search time and fixation times for each condition are summarized in Table 1.

Table 1. The mean search time and mean fixation times of the four conditions[(a)]

	Conditions	Mean search time	Mean fixation times
Alignment patterns	top alignment	9.25E3 (1044.57)	21.42 (2.36)
	distribute alignment	8.27E3 (867.46)	23.25 (2.78)
Route direction	above the bus stop names	1.06E4 (856.81)	26.32 (2.86)
	below the bus stop names	6.93E3 (756.53)	18.34 (2.12)
Gender group	male	8.22E3 (937.38)	19.05 (3.18)
	female	9.30E3 (1041.84)	25.62 (3.54)
Age group	above 40 years old	1.067E4 (1041.84)	27.09 (3.54)
	below 40 years old	6.85E3 (937.38)	17.57 (3.18)

[(a)]Standard errors are given in parentheses.

3.2 Repeated-Measure ANOVA of Search Time Which First Entered the Target Station Region

With regard to the search time, a repeated-measure ANOVA was applied to the search time data of the different conditions, a significant main effect of route direction was found ($F(1,30) = 20.79$, $p < 0.001$), a significant main effect of age group was found ($F(1,30) = 7.74$, $p < 0.05$), and a significant interaction was found, $F(1,15) = 9.29$,

$p < 0.01$. The planned comparisons revealed that the search time of male condition was remarkably shorter than that of female condition ($p < 0.05$), and the search time of the condition that the route direction was below the bus stop names was remarkably shorter than that of the condition that the route direction was above the bus stop names ($p < 0.05$). The results indicated that the main effect of gender group and alignment patterns of was not significant ($p > 0.05$) (see Table 2). It means that the search time was not affected by gender and alignment patterns.

Table 2. Repeated-measure ANOVA results of search time which first entered the target station region.

	SS	df	MS	F value	Sig. (Two-tailed)
Age Group	3.55E7	1	3.55E7	7.44	0.011
Gender Group	4.43E8	1	4.43E8	0.60	0.447
Alignment patterns	2.90E7	1	2.90E7	0.55	0.463
The positions of route direction	4.09E8	1	4.09E8	20.79	0.000
The positions of route direction × Alignment patterns	3.15E8	1	3.15E8	9.29	0.005

3.3 Repeated-Measure ANOVA of Fixation Times in the Middle Station Region

With regard to the fixation times, a repeated-measure ANOVA was applied to the fixation times data of the different conditions, a significant main effect of route direction was found ($F(1,30) = 23.51$, $p < 0.001$). The planned comparisons revealed that the fixation times of the condition that the route direction was below the bus stop names was remarkably less than that of the condition that the route direction was above the bus stop names ($p < 0.001$).The results indicated that the main effect of age group and the interaction of the positions of route direction and alignment patterns was critical significant ($p = 0.056$, $p = 0.058$) (see Table 2). And the main effect of gender group and alignment patterns of was not significant ($p > 0.05$) (see Table 2), which means that the fixation times was not affected by gender and alignment patterns (Table 3).

Table 3. Repeated-measure ANOVA results of fixation times in the middle station region

	SS	df	MS	F value	Sig. (Two-tailed)
Age Group	2746.51	1	2746.51	4.00	0.056
Gender Group	1306.63	1	1306.63	1.90	0.179
Alignment patterns	101.03	1	101.03	0.85	0.364
The positions of route direction	1930.54	1	1930.54	23.51	0.000
The positions of route direction × Alignment patterns	1540.13	1	1540.13	3.93	0.058

4 Discussion

In recent years, eye movement research has been applied to multiple design fields, such as design of webpages, books, city landscape, etc. Researchers answered that design elements of books different formats whether could influence reading velocity or efficiency [13]. In the eye movement observation indicators and under the study of searching performance tasks, one of the main observation indicators was fixation times that users stared at a location, it reflects people information dealing abilities and processing hardness [6]. The more fixation times be used, the less efficiency for searching, it might cause by bad layout display [14]. Early in 1989, Hendrickso regarded fixation times as one of indicators and assessed efficiency of different type menus [14].

Another indicator was the first time to enter target area, which was assessed searching efficiency. More first enter-time indicated more visual searching processing time to get target and lower efficiency of searching activity [14]. The study result revealed that when direction arrows were below station lists, users spent less searching time. It was not the final purpose that direction arrows as sign of judging the bus driving route direction. Therefore, arrows were below bus station lists as reminders whenever needed, it also attracted passengers less attention when they were finding the target station. Further analysis displayed that arrows were below bus station lists which was justify align use less searching time than align top. It provided extra clue for users, saved cognitive recourses and improved searching efficiency.

The same result was found in the test of fixation times that staring at the middle district. When arrows were below the station lists, users spent less fixation times, it means that arrows below influenced users with little interference, and they had greater attention, it was good for target process searching [11]. In addition, similar to the first time to enter target area, further analysis of fixation times of middle district showed that when direction arrows were below the bus station lists,the alignment patterns of justify align spent less fixation times than align top. That is to say, bus stations lists justify align used less time for information processing.

Preceding research proved that less fixation times showed faster processing speed and users could get more processing information. Time length of stare showed difficulty degree of information processed and extracted. Symmetry structure information contains little cognition that was easy to understanding, recognizing and processing. In the research, justify align approaches the style of symmetry structure, which was better for users process information. Therefore, when route direction located below and bus station list justify align, it is a better format design to improving searching efficiency.

Age was remarkably different at the user searching time. The study revealed that, the older users spent more searching time. It was related to many mental functions deterioration with age growing, especially for the cognitive capacity. Based on preceding research, Schaie chose five representative capacities, the ability of inductive reasoning, space orientation, statistics, vocabulary comprehension and vocabulary fluent, which as the basic mental abilities for testing cognitive function. The results showed it was necessary recession with age growing whether horizontal comparison or vertical comparison [15]. It was related to sensory function degeneration in varying degrees, meanwhile, processing rate was reducing and working memory was trending toward degeneration. Some studies indicated that visual function was the mediating variable for the older users' memory width and fluid intelligence, degeneration of visual function was the key in the mental ability ageing [16]. So the study result showed the older users need more time to finish searching tasks, it related to the declining reaction capacity.

5 Conclusion

Bus station board as the necessary public facility for people's travelling, and its humanized degree reflects the developing level of a state or a city. The research indicated that alignment patterns of station names configuration was non-significant difference between justify align and align top, but the positions of route direction was significant difference between above and below, the location below name lists was more efficient. It also revealed that ageing effect was found in the bus station searching test. The study results offered data support for bus stop design. In follow-up work, researchers will continue researching bus station board and relevant facilities from cognitive processing angle, and offer date support for bus station board improvement. Also, they will research for special group such as ageing people, and finally keep the design of bus station board better suit people's needs.

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