THE INFLUENCE OF ENVIRONMENTAL PERFORMANCE ON WAY-FINDING BEHAVIOR IN EVACUATION SIMULATION

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ABSTRACT

Way finding is an important dynamic decision making process in evacuation simulation. Evacuees need to make decision on the next step when there is more than one route or direction ahead. This paper investigates the influence of environmental information on occupants' way-finding behaviour by questionnaire and eye-tracking experiments, supposing that every individual finds his or her own way out and unfamiliar with the building layout. By collecting data on way-finding strategies and participants' visual response to architecture cues, the noticed environment information hierarchy is found and their relations with human characteristics are discussed. The experimental results will not only help to improve the path planning in evacuation simulation models, but also increase the realism of behaviour and response of autonomous virtual humans to surrounding environments.

INTRODUCTION

Way-finding behavior affects circulation trajectory, efficiency and life safety during evacuation process. However, in evacuation simulation, agents are usually deemed to be familiar with the surrounding environment, walking towards exits under certain rules such as shortest path. The environmental information could be recognized only as obstacles or exits in the simulation system. Agents hereby conduct walk towards or away as further reaction (Sun et al. 2010). The visual perception model embedded in the agents only collects very limited environmental information such as distance and location of the obstacles (Reynolds 1982, 1987). Local architectural cues perceived from the built environment and their performances has been persistently neglected.

Very little research has been conducted to investigate the interaction between individual agent and environmental information in both way finding and simulation research. Ozel (1987) suggested individual's architectural cue preference should be measured in a systematic way to improve the accuracy of behaviour simulation in route searching. Sun (2006, 2010) investigated individuals' preference of local architectural cues and proposed a model for evacuation simulation in underground space. Chen (2012) investigated local architectural cues in office environments and built a vision driven simulation system based on it.

This paper investigates how environmental performance affects decision-making and way finding behaviour during evacuation process under normal conditions, in particular the exit information. Firstly, we choose numerous photographs on different decision-making points in public buildings. Secondly, we carry out the eye-tracking experiments with 15 selected photos to find the focus points and questionnaire with 56 volunteers. Finally, the spatial factors with greatest concern are found and their relations with human individual characteristics are discussed. This research finding will help to improve the path planning in evacuation simulation models, and better understand how evacuee responses to circulation design variations in buildings.

QUESTIONNAIRE

To investigate the environmental influence on individual way-finding behaviour and its relation to personal information, the participants were asked to fill a simple questionnaire about their personal information such as age, gender, education level, and evacuation knowledge, fire drill experiences, travel habits and ways to find exits in unfamiliar environments. The following figures were obtained.

There are 56 college students and employees participate in the experiment and questionnaire, within which 54 results are effective. The gender distribution of the participants is 31 males and 23 females, 57.4% and 42.6% respectively. Most participates in the experiment are College-Age students, 33 participants (61.1%) age 18-25, 12 participants (22.2%) age 26-35, 4 participants (9.3%) age 36-45, and 4 participants (9.3%) age 46-55. The distribution of educational backgrounds are including 17 undergraduate students (31.5%), 25 masters and MA students (46.3%), and 12 doctors and Ph. d students (22.2%). Most undergraduate students have fire drill experience due to annual evacuation drill in university dormitory, but very few of them have evacuation knowledge. By contrast, both master and Ph. D (students) barely have fire drill experience, yet have a relatively strong background in evacuation knowledge.

In terms of way-finding strategies in general, the most important being follow the signage, which was chosen by 42 participants (77.8%). Followed by ask other people which was chosen by 37 participants (68.5%), ask the personnel which was chosen by 35 participants (64.8%), and according to the environmental clue which was chosen by 33 participants (61.1%). Then backtrack which was chosen by 19 people (35.2%). Only a few people chose to follow other people (20.4%) and use other methods (11.1%) such as mobile GPS, e-map etc (Figure.1).

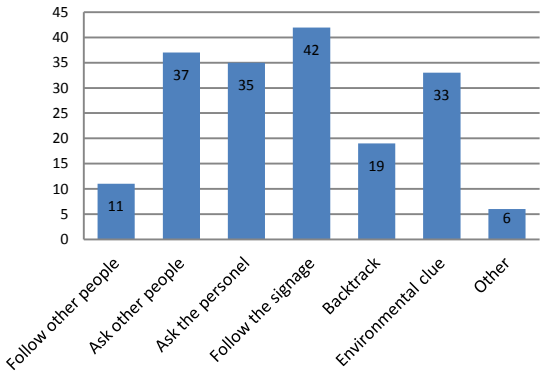

Figure 1 the differences of ways to find exits in unfamiliar environments

Ergonomics study shows that among all information human perceive, over 80% of them are provided by visual organ (Guo et al. 1994). Given the signage and environmental clue were highly concerned by the participants, we conduct eye-tracking experiment to find out which architecture cues cause greater attention in the way-finding process.

EYE-TRACKING EXPERIMENT

Eye tracker is an important instrument for fundamental research in psychology. By recording the eye movement trajectories in processing visual information, it has been widely used in researching attentiveness, visual perception and reading, etc (Duchowski 2002). Such as in traffic psychology, eye track is mostly used on road construction, sign post, visual information search and driver education. Florence Hella (2001) referred particularly the importance of eye-track analysis in dashboard design and research using visual aids technology. Jakob (2006) found most people browsing the web page in F-Shape mode by eye-tracking experiment. Clement et al. (2007) described the impact of visual attention on consumers' in-store buying behaviour through an eye-tracking experiment.

In individuals' way-finding processes, visual cues are the main source in perceiving the built environment. Among all visually perceivable cues, architectural cues have an important influence on individuals' route searching behaviour. To gauge the individual difference in recognizing architectural cues in physical environments, a study was conducted to measure the effects of physical environment on performance (visual search) and process (eye movements). The main task was search for the building exits or exits directions. Fifteen interior photos of decision-making points in public buildings were selected for the experiment. Each interior photo has exit cues and/or distractions and was played 5 seconds in random to the participants.

The heat map, gaze spot and areas of interest could be get from this experiment. The colours on the heat map are used to show heat degree of viewer's eye focus, which is further subdivided into hottest (red), hotter (yellow), not hot (green) and not concern (no colour). Figure 2 shows an example of a collective heat map of an interior space. The attention points, duration and order of fixation could be exported from the gaze spot. Such as in Figure 3, the gaze spots of three participants are shown simultaneously in different colour. The size of the circle shows the gaze duration, which means the larger the circle is, the longer the gaze time. The number inside the circle and links between circles are used to show the order of glance. The areas of interest could also be defined in each photo, so that Tobii system could calculate each area separately and compare the output data such as time and counts (Figure 4).

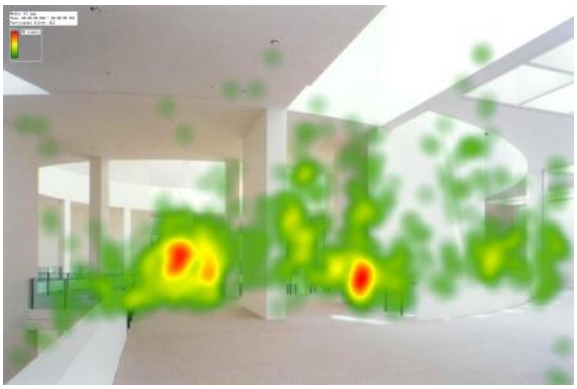

Figure 2 The heat map

Figure 3 The gaze spot

Figure 4 Areas of interest

RESULTS

Way-finding strategies

The way-finding strategies for participants with different age, gender and education background are investigated in the questionnaire. The results show that such personal information has some relation with certain way-finding methods.

Figure 5 shows the way-finding choices of all participants in four difference age groups. Compare with people in other age groups, a much higher proportion of people in age 46-55 chose to ask the personnel and none of them selected backtrack. People in their younger age (18-35) tend to use extra high-tech such GPS or e-map to find their way out of an unfamiliar environment, while no people after 35 made this choice in the experiment.

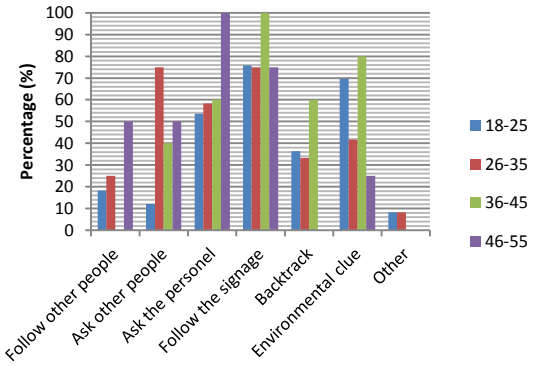

Figure 5 Age differences in way-finding strategies

Figure 6 shows the gender differences in way-finding strategies. A slightly larger percentage of female chose to ask other people (73.9%) and follow the signage (82.6%), while male made up 64.5% and 74.2% respectively. While a much higher proportion of male (71%) chose to follow the environmental information than female (47.8%).

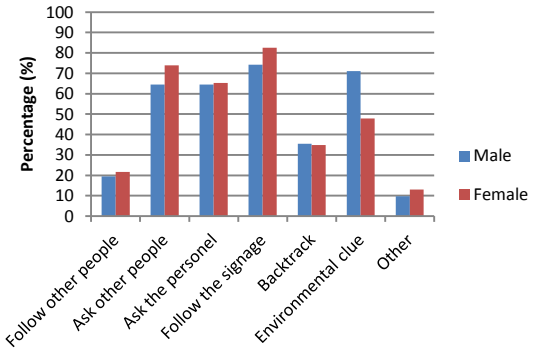

Figure 6 Gender differences in way-finding strategies

Figure 7 shows the way-finding choices by people from difference education backgrounds. The results show that a higher percentage of PhD (students) showed more rational mind and independence in way finding, regardless of whether they have evacuation knowledge and fire drill experience. This group of people have a much higher percentage of backtrack (58.3%), compare to the other two groups (MA-24%, BA-35.3%); a much lower percentage of ask other people (50%), compare to others (MA-76%, BA-70.6%). Besides, they have a slightly higher rate of following the signage and asking the personnel, lower rate to follow other people.

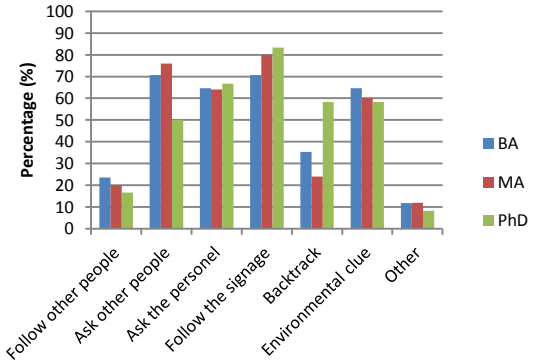

Figure 7 Education background differences in way-finding strategies

Focus of attention

The focuses of attention in 15 photos are investigated in the eye-tracking experiments. There are relatively unclear exits signage in comprehensive environment in 5 photos (photo number 02, 03, 07, 10, 14). The experimental results show that male could find such signage more easily than female. Such as in photo 07 the fixation duration mean on directional signage of male (0.56s) is much higher than female (0.38s) (Figure 8). And in photo 10, the fixation duration mean on exit signage (photo 10) of male (0.44s) is also much higher than female (0.34s). The heat map of photo 02, 03, 14 shows that the heat degree of male's eye focus on the exit signage is in much higher level than female (Figure 9).

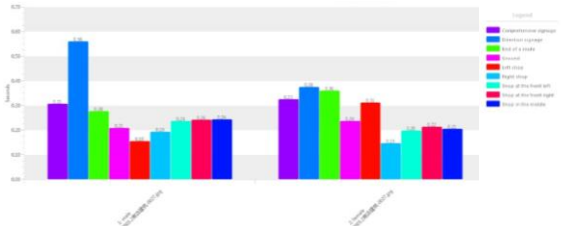

Figure 8 Gender differences in noticing the area of directional signage (Photo 07)

Figure 9 the heat map of male, female and original environment (photo 14)

The results also indicate that there is almost no gender difference if the signage is instantly recognizable or very unlikely to recognize. Such as located at a discreet distance, in distinctive colour or facing directly towards the participants (photo 08, 09), or located too far or too close to the participants, perpendicular to evacuees, which will make all people extremely hard to capture (photo 01, 15).

The gaze spot in three selected photos (photo 02, 04, 09) with clear exit information such as clear exit signage, glass exit door with stairs or outdoor scene are analyzed. The experimental results show that female tend to discover such information more quickly than male, but have also have more chances to miss them (Table 1). In these three photos, the average number of fixation on exit information of male is 8.4, female is only 6.6; while the miss rate of such information of male is 17.2%, female is 21.8%. It seems that no matter how clear and direct the exit information shows, still there would be some people who would not recognize them due to absentmindedness. In addition, the overwhelming majority of people did not capture the exit information at their first glance even though they are very clear in front. The average number of fixation on the clear exit information is the 7.5th.

CONCLUSION

According to the results of eye-tracking experiment, the noticed environment information hierarchy based on importance for all people is found. First level - exit signage, exit door, lighting in front from outdoor; second level - Stairs and guardrail, window with outdoor landscape; third level - glass partition, less distinct alternative route, distinctive colour and shape; fourth level - Exit signage located too close or too far, directional decoration on the roof and ground. This noticed environmental information might change the agents' cognitive maps and knowledge by including possible routes and exits, thus increase the route choices.

Personal information such as age, gender and education level may have certain impact on way-finding strategies. Especially gender difference is found in using environmental clue as a way-finding strategy, ability to find relatively unclear exit signage in comprehensive environment, fixation and miss rate of clear exit information. By giving different weights such as gender differences to agents to represent individual difference of way-finding abilities, individual agents could be more real and diverse.

By now mostly used global way-finding algorithms such as A*, roadmap and navigation graph didn't consider the impact of these factors on the path planning. These findings could provide guidance for evacuation simulation studies by improving the interaction between individual agents and surrounding environments. The actual response to visually perceivable spatial information would also offer settings closer to real world, raise the precision

and accuracy of simulated results. The next step is to conduct larger scale experiments for data collection, statistical analysis and fulfilment of races and cultural backgrounds for developing and improving way-finding algorithms.

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Table 1
Gender differences on fixation and miss rate of clear exit information

	CLEAR EXIT INFORMATION	MALE		FEMALE	
		FIXATION	MISS (%)	FIXATION	MISS (%)
Photo 02	Exit signage and glass door and stairs	8.8	9.6%	6.8	13%
Photo 04	Exit door in glass and outdoor scene	10.2	38.7%	8	48%
Photo 09	Exit signage above the door	6.2	3.2%	5	4.3%
Average		8.4	17.2%	6.6	21.8%