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A VR study

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The impact of guidance information on exit choice behavior during an evacuation – a VR study

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Abstract. This paper presents a Virtual Reality (VR) experiment to study pedestrian exit choice behavior during evacuations. It explicitly investigates whether and to what extent different types of information (i.e. exit signs and directional signs) influence pedestrian exit choice during evacuations. The analysis focuses on the commonalities and differences in the pedestrians' exit choice behavior between the scene without any additional guidance information and two scenarios with different types of guidance information. This study shows that the visibility of exits and direction information towards the exits influence recognizable exits and the final exit choice of pedestrians. However, Fisher-Freeman-Halton exact tests suggest that these influences do not significantly influence pedestrian exit choices during an evacuation.

Keywords: Exit choice, Evacuation, Virtual reality, Guidance information, Exit sign, Pedestrian behavior.

1 Introduction

During a building evacuation, the choice considering the exit to leave a building is vital to pedestrians' survival. Pedestrians usually have a choice of multiple exits and need to decide which one to use [1]. The exit decision is affected by multiple factors, such as the visibility of exits, guidance information provided by signs, lights and sounds [2–4], and the presence of other pedestrians [1, 5, 6]. The relation between those factors has predominantly been investigated using laboratory experiments [3, 4, 7, 8].

Another promising experimental method is Virtual Reality, which can also be used to study pedestrian evacuation behavior. VR experiments can potentially obtain maximum experimental control to analyze the influence of different factors on pedestrian behavior more precisely. Studies have established that VR is a useful tool to study pedestrian behavior during evacuations [9–11]. Yet, to date, few studies have focused on exploring the effect of influential factors on pedestrian exit choice during evacuations with VR. Therefore, there is a need to conduct more exploratory VR experiments to understand how different factors influence pedestrian exit choice behavior and how to implement VR technique to pedestrian study.

This study builds on a valid method to conduct experiments on pedestrian exit choice behavior in virtual environments [12]. It investigates to what extent different types of guidance information present in the environment (i.e., visibility of exit signs and directional information) influence pedestrian exit choice behavior during evacuations. The analysis focuses on (1) analyzing pedestrian exit choice during different evacuation scenarios; and (2) comparing the commonalities and differences in the pedestrian exit choice behavior between the scene without additional guidance information and the scenarios with different types of guidance information.

2 Experimental methods

2.1 Experiment design

A field experiment during an unannounced evacuation drill took place in the building of Architecture Faculty at the Delft University of Technology. The experimental area was a workshop space with multiple exits. A video recording of the unannounced evacuation drill of the workshop space was used as the benchmark for the VR experiment. The camera located at the center of the workshop area, as identified by a circle icon in Fig. 1. The video recording provides a 360-degree view of the space including all exits. All exits can be easily observable from the central spot at which the camera was located.

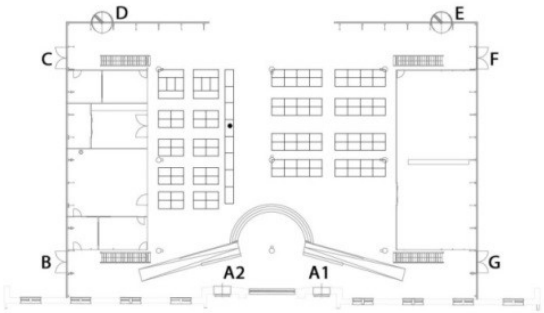
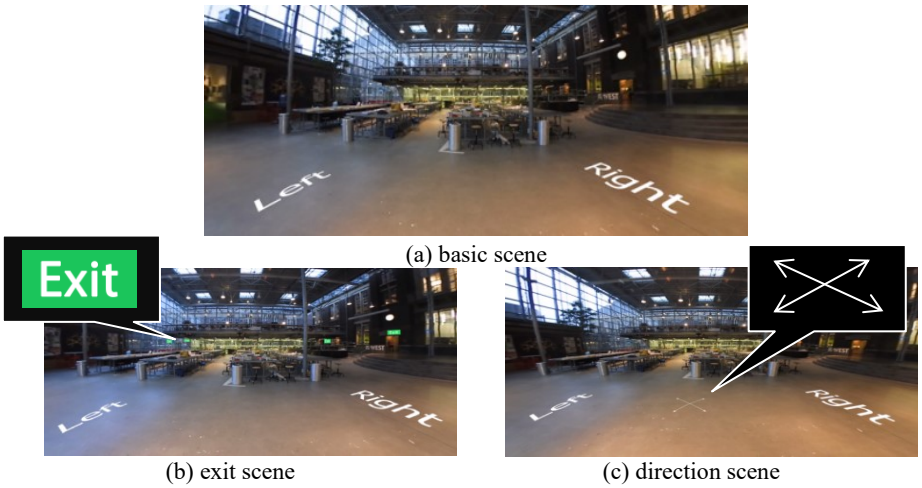


Fig. 1. A schematic illustration of the workshop space.

In order to investigate and compare the effect of different information on pedestrian exit choice behavior, two variables were tested: exit signs near the exits, direction signs on the floor in front of the participant. In total, three different evacuation scenes were created: one basic scene and two experimental scenes, as shown in Fig. 2. The "basic scene" consisted of the recorded area and an added evacuation alarm sound. For the “exit signs” scene, eight emergency exit signs were added to the environment, which were located above each of the exits. For the “direction” scene, four arrows were added on the ground in front of the participant, which point to four exit directions. Besides the three experimental scenes, a general familiarization scene was developed to allow participants to become familiar with the navigation in VR and the sensation of VR.



(a) basic scene

(b) exit scene (c) direction scene

Fig. 2. Screenshots of experiment scenes

2.2 Experiment apparatus

Participants were immersed in the virtual environment via a VR head-mounted display called VR Pro Virtual Reality Glasses (Fig. 3), which has an approximate 90° horizontal and 110° vertical field of view. The virtual environment was presented on a smartphone, the screen was 14 cm length and provided a resolution of 1125 x 2436 pixels for 3D effects.

(a) (b)

Fig. 3. The front view (a) and the top view (b) of the head-mounted display was used during the VR experiment.

2.3 Experiment questionnaire

In order to obtain personal features and experiences of participants regarding the VR experiment, participants were asked to complete a questionnaire immediately after the experiment. The questionnaire contained four sections: (1) participants' information, (2) the Simulation Sickness Questionnaire [13], which determined simulator sickness of participants, (3) the System Usability Scale [14], which assessed usability of the simulator, (4) the Presence Questionnaire [15], which measured participants' experience presence in the virtual environment.

2.4 Experiment procedure

The VR experiment was conducted during the International Festival of Technology on 6th, 7th, 8th June 2018 in Delft, the Netherlands. The VR experiment was approved by the Human Research Ethics Committee of the Delft University of Technology. Participants for the VR experiment were recruited in four ways, namely through the festival website, social media, posters distributed at the university, and direct acquisition of visitors during the festival.

The procedure of the VR experiment included the following parts: 1) participants were introduced to the purpose and instructions of the experiment; 2) got familiar with VR environment and the HMD device (Fig. 4a); 3) were presented with the scenario of the evacuation drill and chose one exit; 4) completed the questionnaires (Fig. 4b).

(a) (b)

Fig.4. Participants were (a) experiencing the virtual experiment; (b) filling in the questionnaire.

3 Findings featuring the impact of guidance information

In total, sixty-three participants joined the VR experiment. The collected data was two-fold: (1) participants' exit choice and (2) participants' experience regarding the VR experiment. Figure 5 presents the mean value of the number of exit participants observed in each scenario. Figure 6 presents the participants' exit choices in each scenario. Although eight exits are available and clearly visible, the exit choices of pedestrians are asymmetrical. The results show that the visibility of exits and guidance information about direction influences the number of exits that the participants can recall and resulting exit choice of pedestrians.

Due to limited sample sizes, Fisher-Freeman-Halton exact test was used to examine whether different types of guidance information have a significant influence on pedestrian exit choice during evacuations. The null hypothesis is formulated as follows: the participant's exit choice during evacuations does NOT depend on the information provided. Fisher's exact test ($p= 0.129$) indicates that different types of information do not have a significant influence on pedestrian exit choices during the evacuation. It might because the results have too many variations, but the sample sizes limit the statistical analysis.

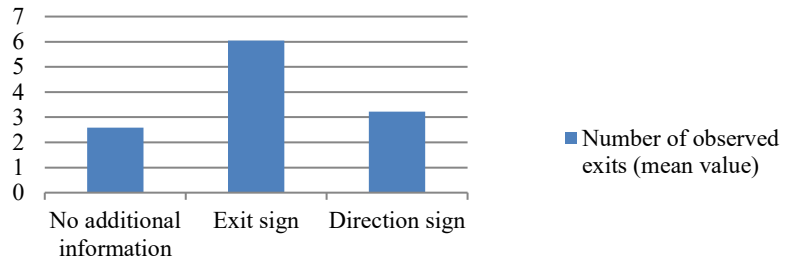


Fig. 5. Number of observed exits by participants

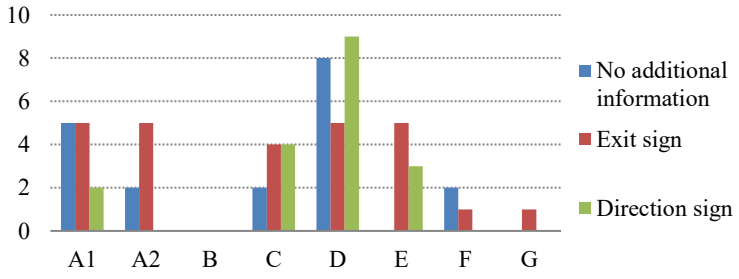


Fig. 6. Participant' exit choice of different scenarios

During the VR experiment, none of the participants showed or expressed (based on the results of the questionnaire) any signs of feeling uncomfortable or asked to have a break during the experiment. Meanwhile, participants stated that the VR simulator is easy to control, and the virtual environment was immersive. From these findings, we conclude that the experiment setting and the VR device are useful to study pedestrian exit choice during evacuations.

4. Conclusions

The present study used the VR experiment to investigate pedestrian exit choices during evacuations featuring three different scenarios. One scenario without additional information, one with additional exit signs and one with additional exit direction signs. The findings suggest that information about exit signs and direction signs affect pedestrian exit choice and number of exits they recognized during the experiment. With the provided information, participants' choices are more diverse. Meanwhile, the exit choices of pedestrians are asymmetrical, although eight exits are available and clearly visible.

However, Fisher-Freeman-Halton exact test indicates that different types of information do not have a significant influence on pedestrian exit choices during the evacuation. In the future, larger sample sizes should be collected to statistically validate the results of this study. Moreover, in order to study pedestrian behavior under more complex situations, the enhancement of experimental setting and VR equipment are required.

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