Are Emergency Egress Signs Strong Enough to Overlap the Influence of the Environmental Variables?

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Abstract. This paper aims to explore the strength of environmental variables (i.e., corridor width and brightness), in directing people to indoor locations during emergency situations. The existence of contradictory information was manipulated by inserting posted signs pointing to the opposite direction to the one suggested by the environmental variables. A Virtual Reality-based methodology was used to collect participants' directional choices. Sixty-four participants had to find a specific room as quickly as possible in a virtual hotel in which they navigated through 12 corridor intersections (two-forced-choices). Two experimental conditions were considered (i.e., Signs and No-signs conditions) according to the exit signs availability. Results indicated that for the first decision point in an emergency situation with signs, 65.6% of the participants preferred to follow the wider corridor instead of the exit sign direction. Percentages of choices favoring the path opposite to that posted by the sign decreased along the escape route suggesting that with the repeated exposure to an exit sign people increased their compliance with it.

Keywords: wayfinding, route-choice, virtual reality, emergency egress, corridor width and brightness, signage.

1 Introduction

With buildings becoming increasingly larger and more complex, the needs of the occupants in terms of accessibility and safety have also significantly increased. Buildings use is now so diversified that sometimes facilities combine the functionalities of a variety of structures such as airports, hotels, shopping center areas, public transportation terminals, apartments, and offices. Additionally, emergency situations and wayfinding generally are not the main focus for developing such

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facilities, and many times, such as in interventions in historical buildings, renovations and changes in buildings use, critical situations may appear. These critical situations could be related to ambiguous situations that arise with the placement of exit signs when they are posted in opposition to the paths that are the most used by the buildings' visitors. Thus, a large concentration of people, with different degrees of familiarity with the building, motivations, and anxieties, has to be able to satisfy their needs in a network of paths leading to different destinations, even when they face doubtful situations created by the incongruence between the architecture and the signage system. Wayfinding within complex buildings can become problematic under normal circumstance but can literally be life threatening during emergency situations, such as fires or terrorist attacks or natural disasters.

Thus, to study these critical situations in which signage points to a direction and people may be attracted to the opposite one by some environmental variables, such as corridor width and brightness, is an important issue to consider when investigating individual behavior during emergency situations. In this sense, with this study we seek to answer a main question: Could the environmental variables influence/disturb the effectiveness of directional signage in an emergency situation?

This current study was made as a continuation of a previous one [1], which had as objective to verify the influence of environmental variables in directing people while in an emergency situation. Results from this study shown that in T-shaped intersections, people prefer to follow by wider and brighter corridors and that brightness is a stronger factor of attraction than width in directing people's movement. In this way, corridors width and brightness can be considered environmental affordances (i.e., implicit information) that somehow inform users about which path to choose. However, according to Tang, Wu and Lin [2], this relationship between explicit (i.e., signage) and implicit (i.e., environmental affordances) directional information is not yet completely understood and should be useful to environmental designers and safety planners by informing them about people's undesired behavior.

Considering these issues, the current study aims to explore the strength of environmental variables (i.e., corridor width and brightness) in directing people during natural movement indoors in an emergency situation (i.e., a fire in a hotel building) and when in the presence of contradictory information (i.e., exit signs pointing to the opposite direction of the environmental variables). Two experimental conditions were considered according the presence/absence of exit signs (sign *vs.* no-signs conditions). To conduct the study, a virtual building was designed and a Virtual Reality (VR)-based methodology was used to facilitate the manipulation and control of the variables, as well as to allow the exposition of participants to a stressful emergency situation without submitting them to a real hazard. The use of VR to study behavior during emergency situations has been studied by Gamberini and colleagues [3]. These authors used VR to examine how people respond during a fire in a public library by manipulating variables such fire intensity and the initial distance to the emergency egress. Their results suggest that users seemed to recognize a dangerous situation within the context of a simulation and readily produced adaptive responses, thereby indicating that VR is a suitable venue for emergency simulations.

2 Methodology

Considering the main research question (i.e., could the environmental variables influence/disturb the effectiveness of exit signs in an emergency situation?) the main hypothesis for this study was that the environmental variables (i.e., corridors width and brightness) can influence the effectiveness of the exit signs. To test this, an experiment using VR was carried out considering the result attained in a previous study [i.e., 1].

2.1 Design of the Experiment

The influence of corridor width and brightness in directing the participants towards an intended direction was tested in two experimental conditions resulting from one factor, the signage presence (i.e., Signs and No-signs conditions). The study used a between-subjects design. The dependent variable is the percentage of choices favoring an predicted direction in twelve corridor intersections. This predicted direction is based on the results attained by Vilar and colleagues [1] considering the location of the variables, considered as attractors (Table 1).

The experimental conditions were:

- No-signs – without any emergency exit signs and in which people were directed only through the environmental variables (i.e., corridors width and brightness), considered as attractors, and;
- Signs – with emergency exit signs pointing to the exit direction, and contrary to the one with the environmental variable (attractor).

2.2 Participants

Sixty-four university students were randomly assigned to the two groups (i.e., Signs and No-signs) as follows. Each group had thirty-two participants equally distributed in to gender. For both groups, thirty participants declared themselves, through a questionnaire, to be right-handed and two declared themselves to be left-handed. For the Signs condition, participants were aged between 18 and 31 years old (mean age = 22.31 years, SD = 3.44), and for the No-Signs condition, they were aged between 18 and 35 years old (mean age = 21.88 years, SD=3.62).

All participants had normal sight or wore corrective lenses and no color vision deficiencies were detected. They also reported no physical or mental conditions that would prevent them from participating in a VR simulation.

2.3 The Scenario (Context and Virtual Environment - VE)

This experiment used a virtual hotel building as interaction environment. For the design of this virtual hotel, there were used twelve corridors intersection previously selected from Vilar and colleagues [1], which can be seen on Figure 1.

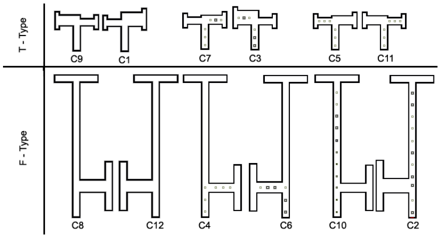

Fig. 1. The twelve "T-type" and "F-type" corridor intersections selected from the study of Vilar and colleagues [1]

Table 1. - Percentages of choice for the twelve most chosen corridor intersections from Vilar and colleagues [1] used as the basis for the design of the virtual building and signs placement.

Corridor intersection	Variable (attractor)	Direction	% of choices towards the attractor
C1	Width	Right	72.05
C2	Brightness	Front	75.83
C3	Brightness and width	Left	87.87
C4	Brightness and width	Right	89.58
C5	Brightness	Left	81.67
C6	Brightness and width	Left	91.25
C7	Brightness and width	Right	89.58
C8	Width	Right	63.75
C9	Width	Left	72.92
C10	Brightness	Front	78.33
C11	Brightness	Right	83.68
C12	Width	Left	57.50

These twelve corridors were those with the highest percentage of choices favoring one of the two alternative corridors. They represent the choice points through which all participants have to pass and to make a directional choice. The percentages of choices for each direction attained in Vilar and colleagues [1] can be seen on Table 1.

These intersections were mixed and then randomly divided into three groups of four corridors each that comprise three sections of the building floor plan. Each section was designed to have the same travel distance, regardless of participants' directional choice at each choice point. Figure 2 shows the top view of the entire VE.

The scenario was generated based on requirements operationalized during systematic meetings involving experts in Ergonomics, Architecture, Psychology, Design and Computer Engineering. Requirements were mainly related to the context, the building's design aspects, the wayfinding tasks that participants have to perform, the navigational aspects and the strategies to enhance the sense of presence and involvement.

For the present experiment, the cover story created was that the participant had to give a lecture in an important conference at a hotel and conference center, however he/she is late yet still has to talk to the receptionist to complete his/her conference registration and to know the location where the presentation will be made. When the participant reaches the second floor where the presentation is to occur, he/she is informed that a fire has been detected on the premises. Figure 3 shows the fire locations within the building.

It was used a controlled navigation strategy in which the corridors already passed by the participant were closed by doors during the wayfinding tasks accomplishment and by fire and smoke in the emergency situation. Thus, for each choice point, when participants chose one of the two alternative corridors, the corridor of the path that was not chosen was closed by a door (or fire), forcing them to continue along their initial selected path. At the beginning of each section, there was a room which was used to deliver the wayfinding task via virtual characters and to calculate the participants' partial performance.

In experimental conditions where posted signs were available (i.e., Signs Condition), exit signs were inserted in the second floor (i.e., emergency situation) of the virtual building. The signs were always positioned to point to the directions opposite to those that were considered the most probable choice (see Table 1) according to the results of the study conducted by Vilar and colleagues [1].

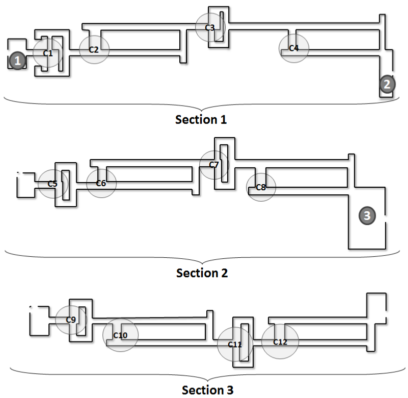

Fig. 2. Top view of the floor plan with the three sections and with the location of the 12 selected corridor intersections. Numbers 1, 2 and 3 show where the wayfinding instructions were delivered to the participants.

Fig. 3. Examples of fire with smoke in the second floor of the VE during the emergency situation

Exit signs are symbol-based and consistent with the International Organization for Standardization's 3864-1 [4] standard. ISO standard exit signs are required by law to illustrate an arrow and running figure in a doorway. Figure 4 shows examples of the exit signs placed in the VE.

Fig. 4. Left image shows the ISO type exit sign, and the right image shows an example of the placement of the exit signs in the second floor

2.4 Experimental Settings

The VE was projected onto a screen using a stereoscopic projector (i.e., Lightspeed DepthQ 3D) and visualized by the participants through active shutter glasses (i.e., MacNaughton Inc.'s APG6000). The projected image size was 1.72 m (59.7º of horizontal field-of-view - FOV) by 0.95 m (35.2º of vertical FOV) with an aspect ratio of 16:9. The observation distance (i.e., the distance between the observers' eyes and the screen) was 1.50 m.

A Logitech®Attack™ 3 joystick was used as an input device to collect the participants' answers. The movement's speed gradually increased from stop (0 m/s) to a maximum speed (3 m/s). Wireless headphones (i.e., Sony® MDR-RF800RK), allowed the participants to listen to instrumental ambient music, the wayfinding task instructions given orally by the virtual characters, and the sounds of a fire siren and fire.

2.5 Procedure

Before starting the experiment all participants were asked to sign a consent form and advised that they could stop participation at any time. The average duration of each experimental session was approximately 30 minutes, divided into a training session and an experimental session. Participants were told that the objective of the experiment was to evaluate new software for VR simulation, so they ought to fulfill some tasks as accurately and as quickly as possible. Participants were unaware of the real objective of the experiment.

The experiment began with the training session which had as main objectives: i) to familiarize participants with the simulation setup; ii) to allow them to practice the use of navigation and visualization devices, to bring their virtual movements closer to their realistic/natural actions; iii) to homogenize differences in the participant's performance using joystick; and iv) to make a preliminary check for symptoms of simulator sickness. Participants were encouraged to explore freely and navigate into the

VE, as quickly and efficiently as they could, without time restrictions. The researcher monitored participants' control of the navigation device by verifying their accuracy in executing some tasks, such as circumnavigating a pillar placed in the middle of a room without bumping into this element and walking through a zigzag corridor without touching the walls. Only after verifying some of these equipment-related skills did the researcher permit the participant to start the experimental session.

At the beginning of the experimental session the cover story was given to the participants: "You were invited to give a lecture in an important conference at a hotel and conference center. The conference staff told you that you must talk with the receptionists to complete your registration at the conference and to know in which room your lecture will be. As the city has a lot of traffic, you are late for your presentation. Please, complete your registration and find your lecture room as soon as possible". Participants were also told that they should behave as they would in a real-life situation. No dialogue between the participant and the researcher was allowed after the simulation started.

The interaction started in the ground floor of a hotel and convention center where participants received three wayfinding tasks (i.e., find three different locations in the building) from virtual characters present in the VE. The last task sent the participants to the second floor of the building via an elevator. Once they exited the elevator, a fire alarm sounded and they were prevented from further elevator use. Thus, participants were faced with finding an emergency egress point by navigating through the second floor in order to escape from the fire. Only the data regarding to the emergency situation, after participants reach the second floor was considered for this paper.

If the participants reached a time limit of 20 minutes inside the simulation, the experimental session was stopped to prevent eye fatigue, or simulation sickness, or both. Simulator sickness was mainly evaluated through participants' verbalizations.

At the end of the experimental test, a post task questionnaire was used to collect demographic information such as age, gender, occupation and dominant hand. Participants were also asked to answer, in seven-point scale format, questions related to their perceived hazard and overall involvement during the interaction with the simulation.

3 Results and Discussion

Results are related to the choices favoring a predicted direction influenced by corridor width and brightness in two experimental conditions: No-Sign, and Signs. Participants' route performance preferences in terms of the percentage of choice were recorded for the entire route (12 corridor intersections). Table 2 summarizes the results obtained. The results are presented according to the corridors disposition on the building's plan. The statistical significance level was set at 5%.

3.1 Environmental Variables: No-Signs Condition

Data related to the No-Signs condition shows that for eight of the twelve intersections studied, most of the participants preferred to follow the predicted direction (i.e., suggested by the environmental variables). The influence of the front corridor was more noticeable, suggesting that participants might have used wayfinding strategies such as the "Least-angle strategy" [e.g., 5, 6-8], and/or the "direction strategy" [9]. This influence can be observed for corridor intersections C4, C6 and C12 (percentages of choices favoring the predicted direction when the front corridor was an available alternative can be seen on Table 2). An unexpected result was also found for intersection C9. In this particular case, participants found the choice point after crossing a room diagonally such that turning right could represent an effect of direction strategy. The decision in this choice point might have been influenced only by a differentiation between corridor widths (right was narrower than left), and it is possible that the environmental variable in this case was not strong enough to superimpose a wayfinding strategy. Also, participants might have been aware of proximal temporal and spatial cues (e.g., the fire direction) that could have influenced their decisions.

Table 2. – Results considering the predicted directions, participants' route performance and percentages of choices favoring the predicted direction for the experimental conditions: No-Signs and Signs. Corridors were arranged according to their disposition on the building's plan.

Corridor	Variable (predicted attractor)*	Predicted Direction*	No-Signs	Signs
			% choice towards predicted direction	% choice towards predicted direction
C1	Width	Right	78.10	65.60
C2	Brightness	Front	81.30	31.20
C3	Brightness and width	Left	90.60	28.10
C4	Brightness and width	Right	31.30	6.20
C5	Brightness	Left	78.10	12.50
C6	Brightness and width	Left	43.80	15.60
C7	Brightness and width	Right	78.10	21.90
C8	Width	Right	56.30	15.60
C9	Width	Left	37.5	6.20
C10	Brightness	Front	68.80	6.20
C11	Brightness	Right	71.90	6.20
C12	Width	Left	28.10	6.20
Participants Route Performance (%)			61.98	18.49
SD			14.03	21.66

*Predicted results were attained from Vilar and colleagues [1] study.

3.2 Environmental Variables vs. Exit Signs: Signs Condition

Data from the Signs condition shows that percentages of choices favoring the predicted direction decreased along the egress route. The highest percentages were achieved in the first three intersections. It is important to note that for the first intersection (C1), 65.6 % of choices favored the predicted corridor (opposite to the way posted by the sign). To explain this trend, it is possible that people did not see the exit sign and they were attracted by the widest corridor, or they deliberately chose to follow the widest corridor ignoring the exit sign. Second and third corridor intersections (i.e., C2 and C3) also presented a considerable percentage of choices favoring the predicted direction. These results are in line with those found by Tang, Wu and Lin [2]. Data from this study do not allow us to determine the causality of the observed route selection behavior, but it is evident that the exit sign in this case was not strong enough to produce a desired safety behavior (comply with the exit sign).

3.3 Post-task Questionnaire

The post-task questionnaire involved questions related to the perceived level of hazard and overall involvement during the interaction with the simulation. Two specific questions of interest were asked: (1) "How would you rate the hazard level on the ground floor (from reception desk, where you received directions to the elevator)? (2) "How would you rate the hazard level on the second floor (when you exited the elevator until you reached the exit door)? Participants responded using a 7-point rating scale (1 – very low; 7 – very high).

When asked to classify the perceived hazard level on the ground floor (i.e., everyday situation), eleven participants classified it as Medium ($N = 64$, $Mdn = 4$, $IQR = 2$). However, when asked about the second floor (i.e., emergency egress), eleven classified it as very high ($N = 64$, $Mdn = 6$, $IQR = 2$). The Wilcoxon Matched-Pairs Signed-Ranks Test was performed and results showed statistically significant differences between the declared perceived hazard level in both floors ($T = 91.50$, $z = -5.131$, $p < .001$, one-tailed, $N = 64$). This finding allowed us to perform a manipulation check because it was confirmed that participants perceived differences between the two situations created, and that the elements (such as flame and smoke, sounds of the emergency alarm and the crackle of wood) inserted into the VE increased their hazard perception in the emergency egress situation.

4 Conclusion

The purpose of this research was to investigate the influence of environmental variables (i.e., corridor width and brightness) in disturbing the behavioral compliance with emergency egress signage when an ambiguous situation concerning wayfinding information is provided. The impact of conflicting information was assessed by creating conditions where signage was present or absent.

The main findings of this study suggest that during emergency egress, participants preferred wider and brighter corridors in a left/right decision, and the front corridor (when it was available), even when it was darker and narrower. In the presence of competing information from exit signs, decisions that favored these environmental variables decreased along the route.

When emergency exit signs are available, results indicated that for the first decision point presented to the participants (i.e., corridor C1), they preferred to follow the wider corridor instead of the direction posted on the exit sign. Percentages of choices where people followed the predicted direction decreased along the escape route suggesting that, with the repeated exposure to an exit sign people increased their compliance with it. Considering only the three first decisions, almost 42% failed the direction posted on the exit sign. A decision to follow the direction opposite of the path to the emergency egress could foreseeably make people walk greater distances and spend more time than necessary to escape from a hazardous situation and could potentially increase the likelihood of injury or death.

Given the main findings from this work, the ISO-type exit signs (static and usually found "running man" sign) for the studied conditions, presented themselves as poor in directing people to a safe place. Other types of signs should be explored. Technology-based signs could be used to increase people's perception about the exit sign even during the first exposure and in situations where conflicting information is present. Technology-based signs could be personalized and more salient than the usual exit signs, they could persuade people to avoid obstructed paths, alert them to the presence of a sign, or even personally conduct users through an egress route by calling their names thereby decreasing the loss of time during pre-movement and movement phases.

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