Virtual Reality Simulation of Architectural Clues' Effects on Human Behavior and Decision Making in Fire Emergency Evacuation

Sh. F. Abu-Safieh

Applied Science University
Amman, Shafa Badran 11931 Jordan
Corresponding author: shaden74@yahoo.com

Abstract Disasters analyses have brought the interest in improving response to emergencies. In many cases there is a need to understand how people within a built environment react in a fire building emergency. Architectural clues play a significant part in the decision making and time taken to evacuate due to an emergency. In this study, virtual reality simulated experiments have been constructed to study the human ability to stay oriented while moving through spaces, evaluating alternatives and making decisions. Two variable models were constructed and implemented in a simulated built environment, in which 100 subjects were tested as in evacuation experiment. Data analysis shows how these variables affect human behavior on each critical decision points. Results showed that some architectural clues such as: windows and colors are important factors in the process of determining and following a route in fire emergency evacuation.

Introduction

In built environments we need to understand human behavior in fire emergency situations. These studies involve the interaction between psychologists, sociologist, engineers, and others professionals.

Most of the evacuation models concern on how people think and act before the start of their evacuation. In fires, there are major factors affecting human wayfinding actions, spatial behavior, and decision making. Such as: persons' age, education, experience, culture, mental and physical capabilities, social situations and architectural clues (Spearpoint, M J., 2008). In building fire cases, people are put in stressful unfamiliar situation, where they have to take rapid decision making using the information that is available. This information collection and decision making may sometimes indicate panic. And this will happen when people are under extreme life threatening conditions especially when they are going through evacuation process (Fahy, 2009). At panic situations, most of the people do not use the emergency direction signs; as a result, they look for other environment's

R.D. Peacock et al. (eds.), *Pedestrian and Evacuation Dynamics*,
DOI 10.1007/978-1-4419-9725-8_31,

clues to escape (Malek, 2006). Achieving an efficient, clear and comfortable circulation system is an important aspect in large complex building.

Many researchers studied the pre-movement behavior model to represent the rational human behavior pattern in fires or emergencies, and to integrate the major variables that affect human perception, cognition process and behavior reactions for people in fire emergency cases. Some were interested in reading supporting information of an emergency task, trying to speed up the time for decision making in emergency situations. While Fire safety engineers try to realize the full value mathematical models that help in human behavior prediction during evacuations. This helps them in designing and implements safety measurements which reduce and control the impact of fire (Chen, 2008).

And to understand the wayfinding process in a complex building, various virtual escape games have been developed. These studies help in explain people's wayfinding behavior in unfamiliar buildings. The aim of this research is to find architectural clues which will help people choosing correct decisions in their decision-making process. We focused on virtual reality simulation In order to predict some spatial clues which people aware of, while performing a wayfinding task.

Background

To understand the human response to clues and decision-making in wayfinding, important concepts and scientific backgrounds for this research have been introduced below.

Spatial cognition

Spatial Cognition is concerned with the acquisition, organization, utilization, and revision of knowledge about spatial environments. This will enable humans to manage basic and high level cognitive tasks in everyday life. Many disciplines work together to understand spatial cognition in humans and in technical systems.

According to Raubal, cognition is acquisition, storage and retrieval, manipulation, and use by humans (Raubal, 2001). Cognitive is part of the mind: brain and nerve system which is part of social and physical world. Location, size, distance, direction, separation and connection are spatial properties. Spatial orientation is one of the cognitive skills and it is the ability to orient oneself in space.

Wayfinding

Wayfinding term has been introduced in the late 70s; it replaced the term "spatial orientation." Wayfinding reflects the approach to studying people's movements and their relationship to space. It is "the process used to orient and navigate. The overall goal of wayfinding is to accurately relocate from one place to another in a large-scale space" (Gluck, 1990). In other words, way finding is "the ability to find a way to a particular location in an expedient manner and to recognize the destination when reached" (Peponis, et. al., 1990). Even more importantly, this approach opens up new ways to design for people's spatial behavior. It is a very important aspect of daily life, especially in emergency situations. In large building complexes, wayfinding shape the setting, affect the choice of the circulation system, and contribute to the design of the interior.

Signs are not the most important means of providing wayfinding information in a built environment settings. People during their movements have to collect circulation information and clues in order to find their way. They have to find out where to enter a building and where to exit it. They have to recognize destination and to identify the horizontal and vertical circulation systems. In other words, they have to understand circulation systems. This will help in their decision-making process.

Evacuation process

Evacuation process contains several overlapping stages: awareness stage, pre-evacuation stage, evacuation stage, and post-evacuation (Spearpoint M J., 2008).

Awareness stage, in this stage people become aware of fire by seeing fire or smoke or by smelling unfamiliar smell or by hearing an alarm system.

Pre-evacuation stage, or the pre-movement stage. In this stage people evaluate the information available and decide their actions. This will last for few seconds or hours. The behaviors in this stage are complicated and a subject of continuous research.

Evacuation stage, after decision has been made, evacuation process will start. If the building is unfamiliar to people they will look for exit route by using their wayfinding strategies. Their decisions depend on individual's perceived level of threat and other behavioral aspects. Choosing the escape rout will depend on the exit route signage: lighted signs, reflective signs, floor lightning, and other means. At the same time, well designed built environment with clear clues will help in this stage, and in correct decision making.

Virtual reality

Virtual is “something that can be done or seen using a computer and therefore without going anywhere or talking to anyone” (Cambridge University Press, 2006). Virtual Reality (VR) has been described as "a magical window onto other worlds, from molecules to minds," (Rheingold, 1991). It helps us in learning how people visualize and interact with objects, in order to enhance their navigational awareness efficiently. In this technique, we can provide a controlled environment in wayfinding researches. VE is a logical technology as an evaluation tool in architecture (Bertol, 1997). VE will allow humans to actively interact with the environment in various ways. De Kort, Ijsselsteijn, Kooijman, and Schuurmans (2003), confirmed that VE could be a prospective tool for environmental behavioral research. According to Riecke, van Veen, and Bülthoff (2002) VE offers experimental research conditions that are easy to define, control, and duplicate. Moreover, VE is able to create experimental research conditions that would be difficult to create in the real environment (Péruch, Gaunet, Thinus-Blanc, & Loomis, 2000). New techniques have been developed by researchers as a Disaster Management Simulator to study the evacuation behavior and the effect of the building design on that evacuation behavior, in particular on way finding (Kobes, 2009) . In this research, virtual environments were used to test some architectural variables and their effect on people’s decisions making.

Methods

Most of the wayfinding problem refers to lack of signage system, or the panic which occurs within people during evacuation in fire emergency cases. And the hardest decision making process while navigate through built environments occurs at the intersection points.

The two experiments in this research focus on environmental clues that perceived by wayfinder while they are trying to solve a wayfinding task in a crisis situation and their actions based on such information. Virtual animated complex buildings were designed to investigate if color (warm / light) and transparency (windows) affect the spatial orientation and decision making of humans during emergency cases. Two different environments were designed to measure this effect. Both of them are consisting of ten T intersections (figure 1).

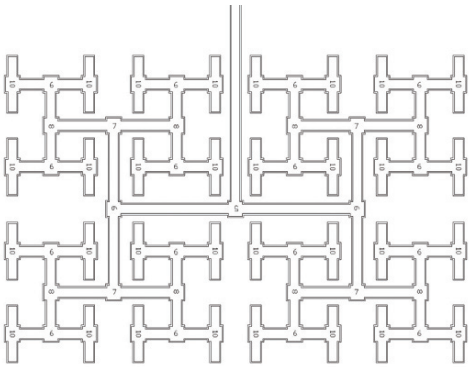


Fig. 1. Floor plan of the animated experiment (ten intersections)

***Experiment 1*:** In this experiment, we intended to test the transparency factor's effect. With different orders two kinds of corridors were distributed at each intersection: the first one has no windows at all while the second one has windows (80% voids) (figure 2). At each intersection, the subjects were asked to choose one of the two corridors they are facing, while navigating to escape from the virtual animated complex building.

Fig. 2. Experiment one - transparency variable

***Experiment 2*:** In this experiment, we intended to test the color factor's effect. Two corridors at each intersection were found. One of them was colored with light color (white, green, blue) and the other with warm color (red, orange, yellow) (figure 3). The subjects were asked to choose one of them during their spatial orientation to escape from the animated complex building.
100 students (53 males, 47 females) from applied science university were participated in this research. Their ages ranged between 19 to 22 years old. The same subjects went through the two experiments in different order at different days.

Fig. 3. Experiment two - color variable

Fig. 4. Experiment two - choosing different light and warm colors

Results

This paper presents a model of the wayfinding process in a fire building emergency. The model integrated elements of people's perception and cognition, focusing

on how people make sense and take of their wayfinding environment and take decisions at intersection points. The wayfinder gains knowledge about the building through visual perception of architectural clues at decision points. One would decide which path to choose with the use of these clues at decision points in order to find his/her way to escape from the building.

In experiment 1, for each subject, the number of closed corridors and transparency corridors which he/she chose were counted. Same procedure was done for experiment 2, where number of light colored corridors and warm colored corridors were counted. The frequency test was applied to the number of transparent and closed corridors for all subjects. Figure 5 shows the relation between the frequencies for each kind of corridors. In figure 6, percentage of each corridors choices, opened and closed, were calculated.

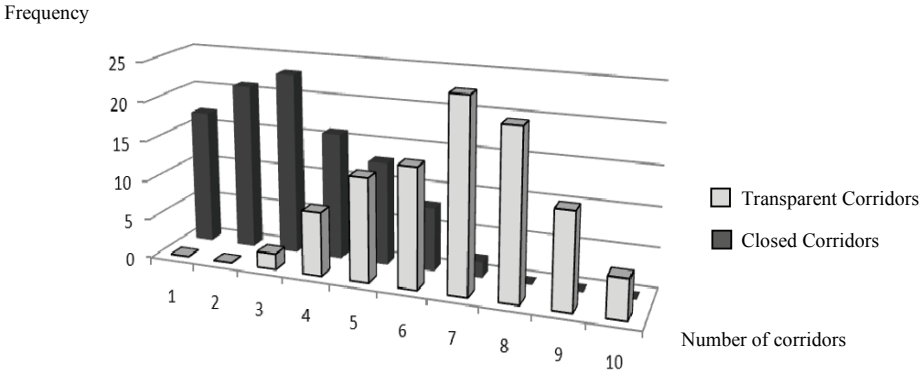


Fig. 5. Frequencies for opened and closed corridors for experiment one

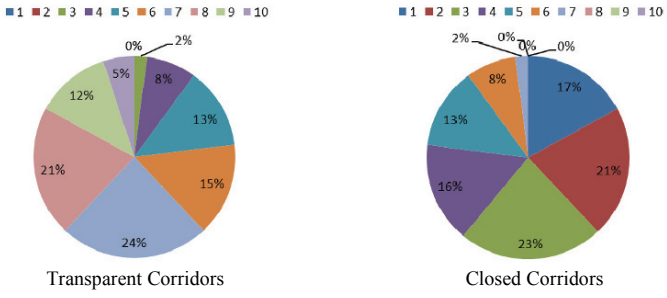
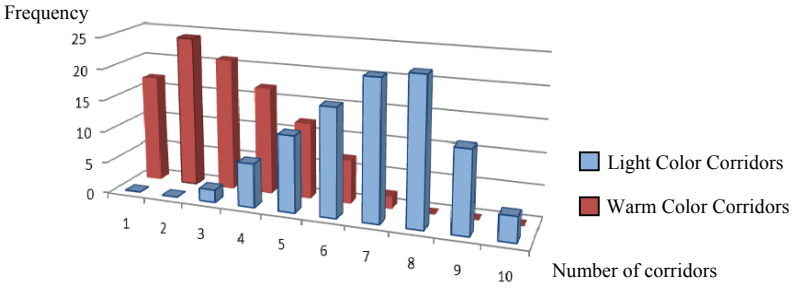


Fig. 6. Percentage of frequencies for opened and closed corridors for experiment one

The frequency test was applied to the number of cool colored corridors and the warm colored corridors for all subjects. Figure 7 shows the relationship between

the frequencies for each kind of corridors. In figure 8, percentage of each corridor choices, cool and warm, were calculated.



Fre-
light
color
for
two

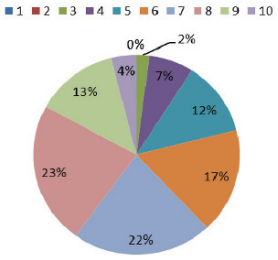


Fig.7.
quencies for
and warm
corridors
experiment

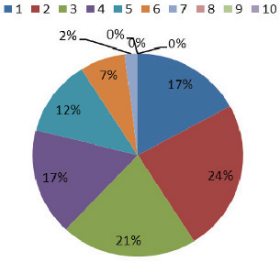


Fig. 8. Percentage of frequencies for light and warm color corridors for experiment two

The average of the chosen transparent corridors was 6.87. Based on this value, the percentage of subjects who chose more than 7 transparent corridors is 62%. This was with a standard variation value of 1.6. These results show that the majority of people are moving towards open transparent corridors during their evacuation process. The average of the chosen light corridors was 6.91. Therefor, and based on this value, the percentage of subjects who chose more than 7 light colored corridors equal to 64%. The standard variation value was 1.6. These results show that the majority of people are moving towards light colored corridors through their process of navigation to escape from complex building during emergency cases.

According to the statistics, there was a correlation value of 0.73. This indicates that there is a strong relationship between the human perception and cognition of the environmental clues (light color and transparency), which affect decision making at intersection points in spatial orientation during fire emergency cases. Figure 9 shows the relation between light color and transparent corridors frequencies.

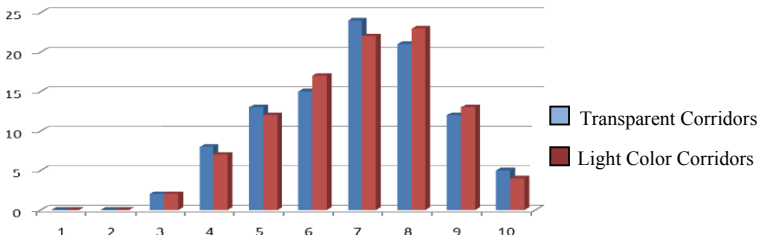


Fig. 9. Frequencies for transparency and light color corridors

Table 1 shows the final results of the frequency test, which were found in the two experiments conducted in this paper.

Table 1. Frequency test results for the two experiments

Number of corridors	Transparent corridors	Light color corridors
1	0	0
2	0	0
3	2	2
4	8	7
5	13	12
6	15	17
7	24	22
8	21	23
9	12	13
10	5	4
Mean	6.87	6.91
Percentage more than 7	62%	64
STDEV	1.68	1.64

Discussion and Conclusions

Virtual environment were used as a prospective tool for wayfinding research because of its ability to control the different variables of the environment. VE also provides similar movement experience as the experiments in the real environment (Raubal, 2001). In this research, by using virtual animated experiments, some architectural clues were tested to improve evacuation plans with lower probability of failure, enabling faster and more efficient evacuation of a building in the event of emergency escape. Hajibabai, et. al found that the better placement of the cues and

optimum planning of the quality and quantity of the signage lead to shorter evacuation time from the building. They proposed strategies which describe how spatial cognition of human can find the exit ways in a building fire emergency by the use of the building signage and the landmarks in such a crisis situation (Hajibabai, et. al., 2007).

This research is focusing on other elements of people's perception and cognition, such as color and transparency, and on how people make sense of their wayfinding environment. There have been different strategies for the evacuation process in fire emergencies. One of them is helping people to use environmental clues in way finding, to enhance correct decisions for escaping from the building. The significance of this paper is the architectural elements in the built environment that helps people in choosing the right path to escape. People need information about the destination to be presented at every decision point (Leila 2006). When we use the transparency in corridors which coming next to each decision making points, we will enhance the ability to collect more information about our environment and our final destination. Moreover it will help people in reducing the panic situation which happened usually in emergency cases.

Many researches investigate Color psychology which refers to the effect of color on human behavior and feelings. They found that color plays a significant role in behavior and performance. For example, "Red turns up on top for associations for a number of different things: angry, aggressive, strong, courageous, frustrated and lustful," according to Stephen E. Palmer, a professor of psychology and cognitive science at the University of California, Berkeley. Orange the color of energy and warmth while green is the color of balance, harmony, caring, tenacious self-reliance, and healing. Blue the color of calmness, concentration, healing, and relaxation. Using light colors like blue, green and white for corridors, will gives people kind of balance, concentration and relaxing at panic situations occurring during fire emergencies evacuation.

Some limitations were noted and could be used as factors for establishing future studies. The experiment was conducted with students most of them are architects and civil engineers. The limited diversity of these participants raised an issue of the external validity of the study, which was the problem of generalizing the Results, because these students might have better skills in understanding building layouts. Additional experiments should be conducted with different types of participants to confirm the results of this study. In addition, individual differences can be an interesting are to study according to the research foundlings.

References

1. Chen, P., Nguyen, T.: Computer-Aided Visual Communication for Wayfinding in Emergency in Indoor environment. The 25th International Symposium on

Automation and Robotics In Construction, June 26-29, Vilnius, Lithuania (2008)
2. Fahy, R.F., Proulx, G.: 'Panic' and Human Behavior In Fire. 4th International Symposium on Human Behaviour in Fire, July 13, Robinson College, Cambridge, UK, pp. 387-398 (2009)
3. Gluck, M.: Making Sense of Human Wayfinding: A Review of Cognitive and Linguistic Knowledge for Personal Navigation with a New Research Direction. Myke Gluck School of Information Studies, Syracuse University, Syracuse (1990)
4. Hajibabai, L., Delavar, M., Malek, M.R., Frank, A.U.: Spatial Cognition and Wayfinding Strategy During building Fire. Dynamic in Spatial Interactions. ICSC (2006)
5. Hajibabai, L., Delavar, M., Malek, M.R., Frank, A.U.: Agent-Based Simulation of Spacial Cognition and Wayfinding in Building Fire Emergency Evacuation. Geomatics Solution for Disaster Management, pp. 255-270. Springer, Berlin, Heidelberg (2007)
6. Kobes, M., Oberijé, N., Groenewegen, K., Morsche, T.: Serious Gaming for Behavioural Assessment and Research in Case of Emergency: An Evaluation of Experiments in Virtual Reality. Netherlands Institute for Safety, Arnhem, The Netherlands VU University Amsterdam, The Netherlands (2009)
7. Passini, R.: Wayfinding in Architecture, Second Edition. Van Nostrand Reinhold, NY (1992)
8. Peponis, J., Zimring, C., Choi, Y.K.: Finding the Building in Wayfinding. Environment and Behavior, 22-5, pp. 555-590 (1990)
9. Péruch, P., Gaunet, F., Thinus-Blanc, C., Loomis, J.: Understanding and learning virtual spaces. In: Kitchin, R.M., Freundschuh, S. (eds.), Cognitive mapping: Past, present and future, pp. 108-124. Routledge, London (2000)
10. Proulx, A.: The Use of Virtual Environment as a method of wayfinding research in architecture (2006)
11. Raubal, M.: agent based simulation of human wayfinding: a perceptual model for unfamiliar buildings. PHD thesis, Vienna University of Technology, Astria (2001)
12. Riecke, B.E., von der Heyde, M., Bülthoff, H.H.: Spatial updating experiments in Virtual Reality: What makes the world turn around in our head?. Tübingen Perception Conference (TWK), p. 162. Tübingen, Germany (2002)
13. Satalich, G.A.: Navigation and wayfinding in Virtual Reality. Finding the Proper Tools and Cues to enhance Navigational Awareness. Washington (1995)
14. Spearpoint, M.J.: Fire emergencies and people. New Zealand Science Teacher. No. 117, pp. 14-16 (2008)