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Perceptual and Cognitive Factors that Influence Orientation in Computer Generated Real Architectural Space

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This study presents results from an experiment that concerns spatial perception and cognition in virtual environments. It also includes the effects of how the development of a simulated virtual space can change perception and cognition of a real building perceived only through architectural drawings and photographs. In the experiment each student was shown external and internal 360° images, representing nodes in virtual space, of the same virtual building. Two different groups of students were formed. The first group was shown photorealistic rendered images, while the other group the same images with non-photorealistic representation. Differences in orientation tendencies of the participating students, as well as statistical results from these experiments were tested and are presented in this paper. It was found that there was a statistically significant tendency of the students towards larger scatter in more luminous virtual space as well as a tendency to visit lit parts of virtual space.

1. Introduction

Virtual environments (VEs) have been efficient in our days for training and skills in 3D space [1, 2]. These applications require the trainees to become familiar with the characteristics of computer-generated environments and to apply their knowledge to the real world; however the differences of real world and virtual environments in distance perception, navigational awareness, landmark recognition, spatial ability, the individual differences of trainees in prior experience towards computers and interface expertise and wayfinding, which is described as the ability to find a way to a particular location in an expedient manner and to recognize the destination when reached [3], have all been the topic of several studies that have examined these aspects in VEs [4].

The complete navigational knowledge of an environment is known by the term navigational awareness. There are two types of navigational awareness: the first is procedural, which is ego-referenced and is usually acquired by the exploration of a new area, and the second is survey knowledge, which is acquired after multiple exploration of an environment using multiple routes. The differences between the procedural and survey knowledge is that the person who has procedural knowledge can move successfully from one landmark to another but does not know alternative routes. Survey knowledge characteristic is that it is world referenced. Therefore, although the trainee who acquires procedural knowledge can navigate through the 3D model successfully, it is the survey knowledge which is referred as a "primary" experience in a virtual space [5]. The reason for better judgment of distance for a specific route traveled is because learning is formed by sequential travel. Knowledge of relationships of places along this route are unidimensional, thus a student will be better at recalling when it is in the direction they learned the route [6].

To reach the level of navigational awareness by exploring a 3D model in a VE, the trainee must go through a process called dynamic process or 'Sequential and Hierarchical" model, as described in Siegel & White [7]. To achieve this, four steps are required. The first and second steps are necessary for the procedural knowledge and the third and fourth for the survey knowledge. The first step is landmark recognition, where objects become landmarks for their distinctiveness and their personal meaning [8]. The second step is characterized by the routes and links formed as the trainee is traveling between two landmarks. The third step is the primary knowledge acquired by the significant traveling through the routes in the VE. The fourth step is the secondary knowledge which involves the use of maps in order that the trainee learns more about the VE.

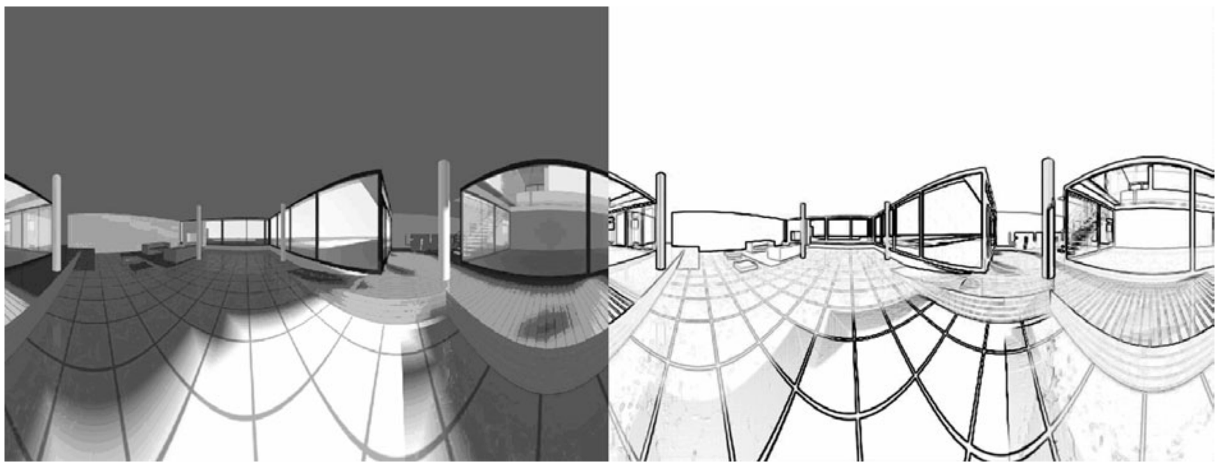
This paper is based on research with a group of undergraduate students in the field of architecture that are participating in one of the final courses for the completion of their degree requirements. The course is based on using and exploring the computational tools used in computer aided architectural design to reveal and reinstate or replace known parameters and experiences referred to architectural design. Through this course, methods and procedures are explored and analyzed, by which the above mentioned tools can be used to amplify space perception and cognition, which, in turn, can supplement architectural design during the stages of analysis, conception, implementation, evaluation and communication. Some of the initial exercises included the development of a presentation video referring to a computer generated 3-D model of a building. The students were divided into groups and were called upon to select a small, easily comprehensible building. A written report was asked with a proposal for a walkthrough in the building based on a hypothetical scenario by using a storyboard and a movement diagram on the plan drawings. The groups were educated on the basic principles of cinematography and movement over time in 3-D space and they concluded their exercise with a video presentation of their walkthrough. The evaluation of the results included the comparison of the final walkthrough scenario and movement diagram with those proposed initially in the written report. It also included the effects of how the development of a simulated virtual space can change the perception and cognition of a real building perceived only through architectural drawings and photographs. The results showed that about 20% of the final walkthrough scenarios tended to review or totally change their initial scenario after they got acquainted in the 3-D virtual space. These differences provided the stimulus for this research as explained below.

2. The experiment

In the experiment each student was examined in the same room, on the same computer, with the same lighting conditions and was interactively shown external and internal 360° images, representing nodes in virtual space in which they could move about by selecting an alternative node, thus producing a path. Two different groups of students were formed. The first group was shown photorealistic rendered images (PR), while the other group was shown the same images with non-photorealistic representation (NPR). The method of non-photorealistic representation was included to identify parameters that are used for movement through a virtual space without the interference of lighting, shadows, colors and textures because NPR methods allow us to emphasize or omit detail in order to communicate information more effectively. All the students were asked to move through a virtual building by moving from one node to another being free to select their path. The experiment involved 40 students of which 20 where given a PR three-dimensional model and 20 a NPR of the same three-dimensional model.

The model that was used for the experiment was a house designed by Marcel Breuer in Feldmeilen, Switzerland [9]. This project was chosen mainly because the effectiveness of moving through it by offering both simple and complex orthogonal spaces and was designed using a grid. Through its orthogonal layout of the plan the visual cues and access of the corridors and the rooms is very efficient for the comprehension of the plan, as well as the layout of the external spaces through which one can witness the external form of the building, as well as gain access to different spaces. It is also divided into five distinct zones: the living room, the bedrooms, the kitchen, the housekeeping, the children and finally the working space, thus being helpful to the distinct incorporation of objects and furniture that would make the comprehension of the building easier. The building was three-dimensionally digitized producing a model with materials, textures and lighting that resemble reality.

The methodology used for the experiment can be described as follows. Students were provided with interactive rotating panoramic images of the model that were linked to each other and were instructed to navigate through the model. These interactive rotating images represented nodes in the plan of the building, through which the statistical calculations of the results could be made more efficient. The number of sequential moves each student could do was limited to 25 and the only guideline that was given was to first make a full rotation of the panoramic image before they make their next move. The goal of this experiment was to distinguish the differences between the two groups in the routes they chose, the places that were disorienting and how the representation of the model influenced their decision according to their perceptual field [10], which corresponds to their perception of form, order, succession and variation. Additionally, their depth and distance perception was noted, along with how many objects they remembered finding during their navigation in the 3D model. Figure 1 shows a typical PR and NPR configuration of one of the virtual spaces (node) which were visited by the students.

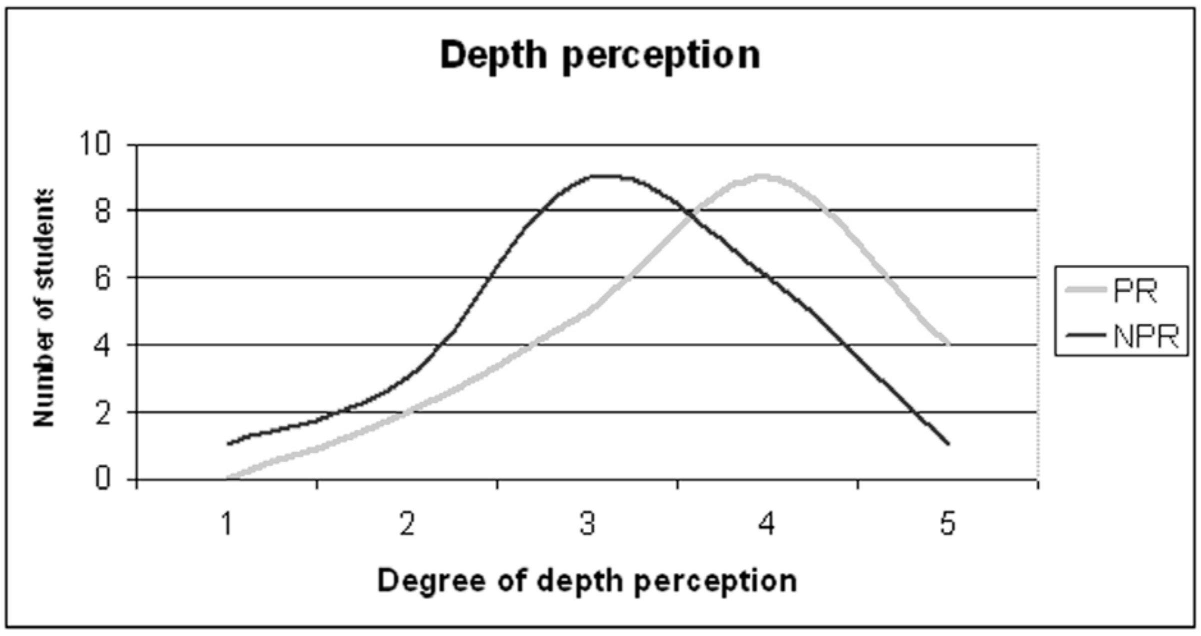


▲ Figure 1. Left: Typical PR of one of the virtual interactive spaces (node) of the building. Right: Typical NPR of one of the virtual interactive spaces (node) of the building.

3. Results and conclusions

Figure 2 shows the density of the visits on each node both for the PR (left) and the NPR (right). Each node is color-shaded according to the number of visits. The darker the color, the more frequent the visits that were counted. The comparison of these two figures in connection with the interviews at the end of the walkthroughs reveals that the students that navigated in PR nodes got a better understanding of depth in the VE than those that were given the NPR ones. This is seen more clearly in Figure 3 which shows two curves representing the distribution of the perception of depth (on a scale from 1 to 5) measured for each student for the PR and the NPR cases respectively. As it appears from Figure 3, the curve in the PR cases is shifted towards higher ranking in understanding depth in the VE. An additional proof of that can be noted by the routes that the students followed in each case: the PR walkthroughs were concentrated mainly towards access points and corridors through the building, most probably due to the students' better understanding of depth. This resulted that those students did not feel the need to travel to a node that was closer to any far away object. More specifically, any object in their line of sight could be identified from a distance and therefore the students considered that they had visited not only the nodes they did, but also the neighboring ones. The opposite was true in the majority of the NPR cases, in which the understanding of depth was ranked lower than in the case of PR. Therefore, nodes that contained objects such as the dinning room, the living room etc. were visited more often in the NPR cases than the PR ones.

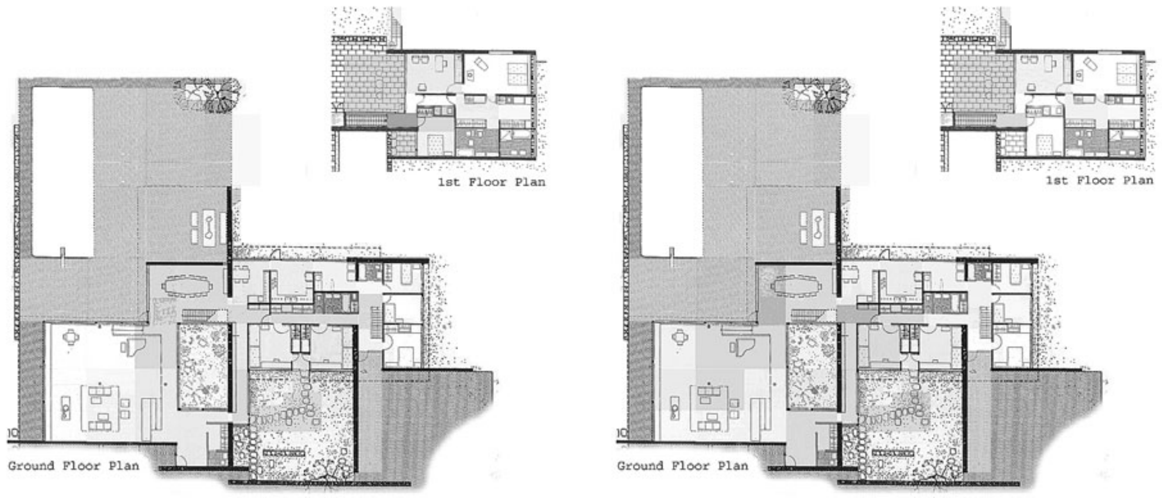
▲ Figure 2. Left: Density of the visits on each node for the PR through color-shading on the plan of the building. Right: Density of the visits on each node for the NPR through color-shading on the plan of the building.



▲ Figure 3. Distribution of the perception of depth (on a scale from 1 to 5) measured for each student for the PR and the NPR cases respectively.

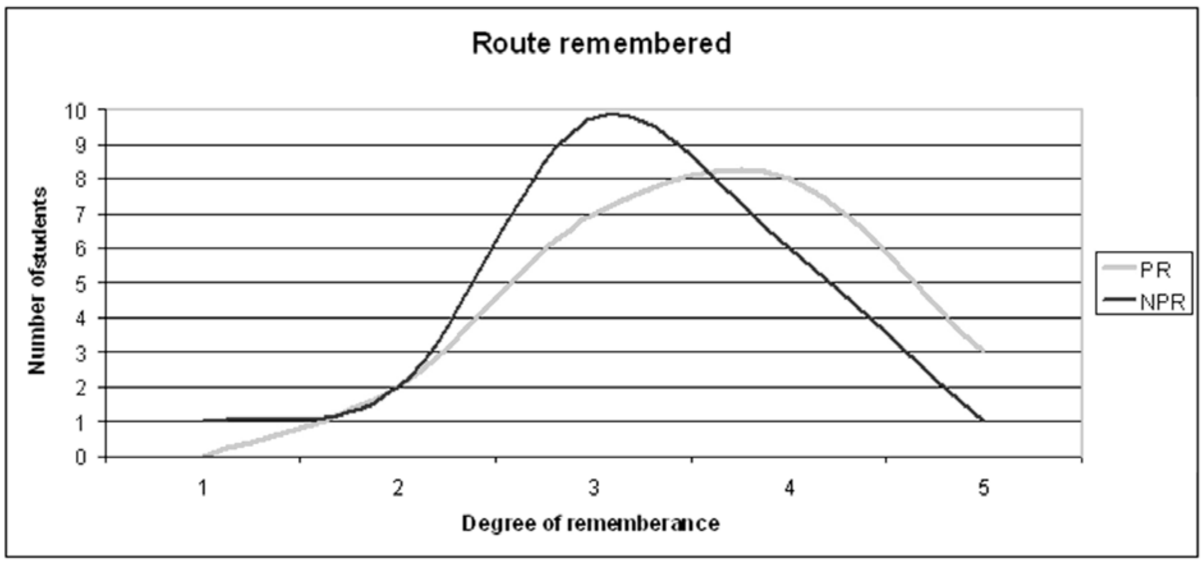
Another interesting result which emerged from this study was the finding of a general tendency of students that participated in the PR part of this experiment to visit spaces with higher luminosities. This can be attributed to the fact that humans, as most animals do, are attracted to light and brightness. Therefore, apart from the nodes used for circulating, the ones that were visited most were those with high contrast between shadows and direct sunlight. A general rule of thumb can be made that visitors tended to scatter more in high luminosities of the images visited. NPR images have higher brightness in comparison to PR images, under the same conditions, because lighting conditions, shading and colors are not shown and thus the scattering in the NPR walkthroughs was higher. As a conclusion, if someone is asked to explore a VE efficiently a NPR is most probably a better choice of representation than a PR.

Two other factors have been checked in this study i.e. the previous experience in navigating in a VE mainly through 3D games, and the rememberance of the paths the students followed between nodes. It turned out that experienced students could do a faster and more efficient navigation but the nodes they visited had no statistical difference in PR and NPR when compared in analogy to the results obtained from Figure 2. The densities of the nodes visited for both PR and NPR are shown in Figure 4 and Figure 5 for the students that were experienced in navigating through VEs (mainly through the use of three-dimensional computer games) and for the students that were not respectively. Finally, as to their rememberance of the path the results proved to be statistically non different in both cases (PR and NPR), despite the fact that the curves shown in Figure 6 are slightly different.



▲ Figure 4. Lft: Density of the visits on each node for the PR through color-shading on the plan of the building of students that were experienced in navigating in VEs. Right: Density of the visits on each node for the NPR through color-shading on the plan of the building of student that were experienced in navigating in VEs.

▲ Figure 5. Left: Density of the visits on each node for the PR through color-shading on the plan of the building of students that were not experienced in navigating in VEs. Right: Density of the visits on each node for the NPR through color-shading on the plan of the building of students that were not experienced in navigating in VEs.



▲ Figure 6. Distribution of the degree of rememberance of the routes (on a scale from 1 to 5) measured for each student for the PR and the NPR cases respectively.

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