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An Exploratory Study on the Relationship between Orientation Map Reading and Way-finding in Unfamiliar Environments

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1. Introduction

There are many ways to familiarize oneself with an unfamiliar environment, but most people use orientation maps to help them. In more complicated buildings, orientation maps may be posted everywhere, since they serve as important references for spatial cognition and way-finding for users. A study on way-finding by Best (1970) identified a positive relationship between the number of choice points (hallway intersections) within a building and way-finding difficulty. Weisman (1981) defined a number of environmental variables that people use to help orient themselves during way-finding, and categorized these variables into four classes: (1) *signs*, which provide directional information within a setting; (2) *perceptual access*, which provides a view to landmarks within or exterior to a building; (3) *architectural differentiation*, which is the ease with which different regions or landmarks within a building can be recognized; and (4) *plan configuration*, which is the configuration of a building's floor plan. Beaumont *et al.* (1984) interviewed building occupants and found that the layout of floor plans is equal in importance to other architectural features, such as the availability of signs, with respect to reported ease of way-finding. O'Neill (1991a) found that incremental increases in floor plan complexity reduce both the accuracy of one's cognitive map and one's way-finding performance. O'Neill (1991b) also found that floor plan complexity reduces way-finding performance, despite the presence of directional signage. Nichols *et al.* (1992) reported that the primary cause of way-finding difficulties in transportation centers is the complexity of possible paths. The accuracy of the information in one's cognitive map can influence one's way-finding performance (O'Neill, 1991a, 1991b). The cognitive map can store *route* and *survey* representations (Tolman, 1948), where *route representations* contain knowledge about individual places and the way in which they are connected through experience; in other words, the 'travel-ability' that exists between places (Kuipers, 1983). Montello (1991) proposed that the asymmetric structural design of streets is likely to mislead users: subjects tend to make more mistakes pointing out the position of an object and direction (east, west, south, and north) when on asymmetric streets than on intersecting ones. Passini (1999) argued that the acquisition of knowledge about places plays an important role in way-finding and determines one's chance of finding one's way successfully. If pedestrians acquire incorrect information about a place during way-finding, the chances are that they will get lost.

As for how environmental design contributes to effective way-finding, Lynch (1960) pinpointed many concepts from which subsequent researchers can learn. According to Lynch (1960), an environment should have, among other things, the following elements - paths, edges, districts, nodes, and landmarks - because they offer environmental clues during way-finding. Darken (1995) also believed that environments without proper structures are not preferred, because men normally feel terribly uncomfortable in an environment in which there are no clues for reference; they rely heavily on any environmental structures or objects to determine what direction they are pointing and which direction to take.

One's cognitive map reflects one's mental image of a place. A distinction must be made between two concepts - *cognitive map* and *cognitive mapping*. The difference between them is that *cognitive mapping* is a dynamic process, during which information about individual's spatial environments are processed, whereas a *cognitive map* is a network concept that represents the relative locations between different objects (Johns, 2003). Garling *et al.* (1984) used a vivid example to illustrate this difference: "a cognitive map is like an end product, whereas cognitive mapping is similar to the process of acquisition." A cognitive map cannot reproduce the original environment completely: on the contrary, it is a product constructed by each human's cognitive system (Tversky, 2000). According to Tversky & Lee (1998), a cognitive map demonstrates spatial information complementarily, in both illustrative and descriptive fashions. Elvins (1997) identified three important facets of a cognitive map – it must be identifiable; it must be structural; and it must be meaningful; in other words, the objects in an environment must be identifiable and comprehensible to be preserved within a person's cognitive map. Other empirical studies also have shown that individuals will attempt to seek out whatever reference points they can identify, when trying to find their way, so as to reorganize information about an unfamiliar environment. The subsequent storage of these points in the cognitive map indicates that landmarks are visual, cognitive, and structural, as proposed by Sorrows and Hirtle (1999). Furthermore, Golledge & Stimson (1997) reported that cognitive mapping is a process that builds understanding about different environments, and interprets and deals with a series of complex information. This so-called 'information' is not only spatial; it also refers to the value and meaning of a place's existence. The cognitive map, on the other hand, is concerned with the retrieval and use of an object from spatial knowledge as an anchor, after the acquisition of spatial knowledge, and is the linking of all the anchors in an environment to establish an interdependent network, which is the so-called cognitive map. It can be referred to as a map previously saved in the human brain, so that one has a clearer picture of the complete layout of a place (Golledge, 1999). As a result, an accurate and complete cognitive map is a key determinant of successful way-finding performance. Kitchin (1994) gave direct support to the idea that it is imperative to formulate a cognitive map. He believed that the main function of a cognitive map is to tackle spatial problems, which primarily are way-finding and navigating processes.

From the viewpoint of Evans (1980), people are more likely to feel well oriented in buildings consisting of regular structures (such as a crisscross or a right angle) than in those with irregular structures and/or angles. The concept of the cognitive map can be dated back to 1913, when Trowbridge conducted a study and concluded that behavioral responses to environments confirm the existence of image schemas in human cognitive systems. In the study of Liben (1981), in terms of spatial ability and spatial representation, a cognitive map contains four types of composition difference which are *spatial product*, *spatial thought*, *spatial*

storage, and *memory storage*. Montello (1999) defined *spatial ability* as the ability to use maps, explore new environments, and describe a surrounding, using words, in a very large space in the real world. Collins and Quillian (1969) proposed that the knowledge system of human beings is a hierarchical network. The issue of how human internal cognitive systems interact with the external environment during way-finding, thereby influencing way-finding performance, should be addressed (Garling *et al.*, 1984). The information about the environments in which human beings exist can be subdivided into three categories: *information about location*; *information about properties*; and *information about time*. The three categories of information determine the behaviors and activities of men moving between locations (Krieg-Bruckner *et al.*, 1998). Siegel and White (1975) outlined three learning steps that occur while one acquires spatial knowledge: *landmark recognition*; *path/route development*; and the *coordination of clusters*. For Thorndyke and Hayes-Roth (1982), spatial knowledge comes from paths and from a bird's eye view. Passni (1939) stressed that the understanding of spatial orientation plays a fairly important role as people develop a concept of space, and it is the generic term for direction and location. Judgment on orientation is closely interrelated with that for direction, because both represent the ability to continuously move forward. One can identify his own position based on his location relative to things around him.

Zeitzer (1994) stated that virtual reality is an advanced user interface which generates real-time simulations and interactions through many sensory modalities. Wilson (1999) pointed out that virtual reality enables users to observe simulated worlds from any perspective, and to further interact with any objects in those worlds. Weyrich (1999) noted that virtual reality, which is generated by computer models with the integration and application of computers and peripherals, creates three dimensional (3D) scenes through which users can navigate. When in virtual reality, users activate their perceptual and cognitive systems, as they do in the real world, to interact with simulated objects, and the experience is very close to those of the real world (Stanney, 2003). Considerable research on spatial cognition, like studies on human beings' way-finding performance, has employed virtual reality as a medium through which to understand navigational behaviors (Darken & Silbert, 1996). Virtual reality is an appropriate research medium for studying spatial cognition, because the investigators have total control over operating the variables; and they are able to simulate and represent any environments, real or hypothetical (Jansen-Osmann, 2002). Since virtual reality is a computer-simulated environment, computers can conduct real-time calculations, based on user behaviors, and respond with suitable simulated scenes that users are supposed to see (Grammenos *et al.*, 2002). Among the benefits brought about by virtual reality is that researchers can add different environmental variables, on their own terms, to control the variable that might affect way-finding performance, something which is less likely to be orchestrated in the real world (Booth, Fisher, Page, Ware, and Widen, 2000). The evidence provided by Witmer, Bailey, Knerre and Parsons (1996) indicate that the route knowledge gained by participants in highly-simulated worlds is transferred to and applied in real life successfully.

In addition, Tang *et al.* (2008) once conducted an experiment on reading cognition and way-finding, using building evacuation plan diagrams without virtual reality, and the result revealed that different backgrounds do affect diagram-reading and way-finding. As a result, this study aims to investigate the relationship between the orientation of maps and the reading cognition of users. Our specific objectives are as follows:

1. To probe the time required to read and comprehend orientation maps, in order to examine the level of descriptiveness of existing maps;
2. To analyze factors that lead to differences in map cognition, so as to reduce the gap in reading cognition; and
3. To examine the correlation between map-reading and way-finding, in order to measure the efficacy of maps in way-finding.

2. Methods

2.1 Simulated space

The simulated buildings used in this experiment represented two hospitals, and the simulated areas included the ground and first floors. On each floor were four emergency staircases that led to other floors. The building at the front was 15 m tall and 36 m wide; the other building, at the back, was 20 m tall and 56 m wide, with a ceiling height of 3.2 m. The area of one floor was roughly 1660 m². The front building housed the reception and registration desks; the rear building housed the emergency room and several consultation rooms. In addition to the four emergency escapes, an additional seven public elevators and two elevators for sickbeds were arranged in a crisscross pattern. The only corridor, which was 2.5 m wide, connected the front and rear buildings.

2.2 Experimental facilities

The computer employed to conduct the experiments was an ASUS V6 laptop. A DLP projector, serving as the user interface for the experiment, was connected to the laptop. The simulated scenes were presented on an 80″ color screen with a screen resolution of 1024×768. The ambient illuminance for the experimental environment was measured by SEKONIC L-508. The design of the simulation workstation is shown in Figure 1. The monitor was placed above the desk, which was 75 cm tall, and the centre of the screen was 40 cm above the desk, with a screen inclination of 90 degrees. The above-mentioned figures were fixed and not subject to change. Prior to the experiments, subjects could adjust the height of their chair accordingly; the visual range was set at 250 cm.

2.3 Design of the experiment

Prior to their participation, subjects were informed that they were to be in a simulated way-finding experiment. The path of the simulated journey was set to start in the lobby on the ground floor (starting point), and then proceeded through a corridor and up staircases, to the final destination (the blood draw room on the first floor). The maps provided are shown in Figure 2. Since floor plans are posted at elevator lobbies at the scene, the computer also simulated the floor plans for this experiment (see Figures 3~4). Figures 5~10 demonstrate the simulated nodes. During the experiment, subjects moved a mouse to simulate the way they would travel through the buildings. By left clicking and dragging the mouse button, subjects moved ahead (at a speed of 1 m/sec); conversely, right clicking and dragging the mouse caused them to step backwards. Subjects could turn left or right simply by moving the mouse in the desired direction.

2.4 Participants

A total of 45 subjects completed the study. They were comprised of both students and members of the general public who agreed to participate in the experiment. To be eligible,

an individual had to have a basic working knowledge of computers. Twenty-three of the 45 subjects were male (51.1%) and 22 were female (48.9%); 21 (46.7%) of all participants were architecture- or design-related professionals. The vast majority of subjects (91.1%) were between the ages of 20 and 39 years. No subject was color blind or had any eye disease, with all corrected eyesight between 20/25 and 24/20. All were tested once only. No subject was permitted to observe other subjects being tested.

Description: the term 'front building' refers to the map posted in the elevator lobby in the front building; and 'rear building' refers to the map posted in the elevator lobby in the building behind it. Each map shows the floor plan of the building in which it is located. Since maps were posted in different locations, the floor plan for the ground floor of the rear building is rotated 90 degrees.
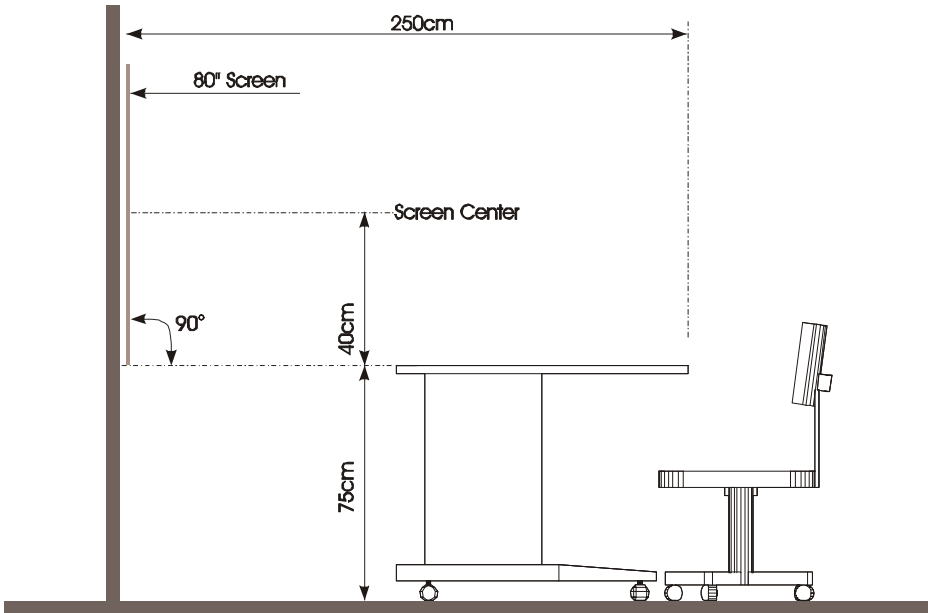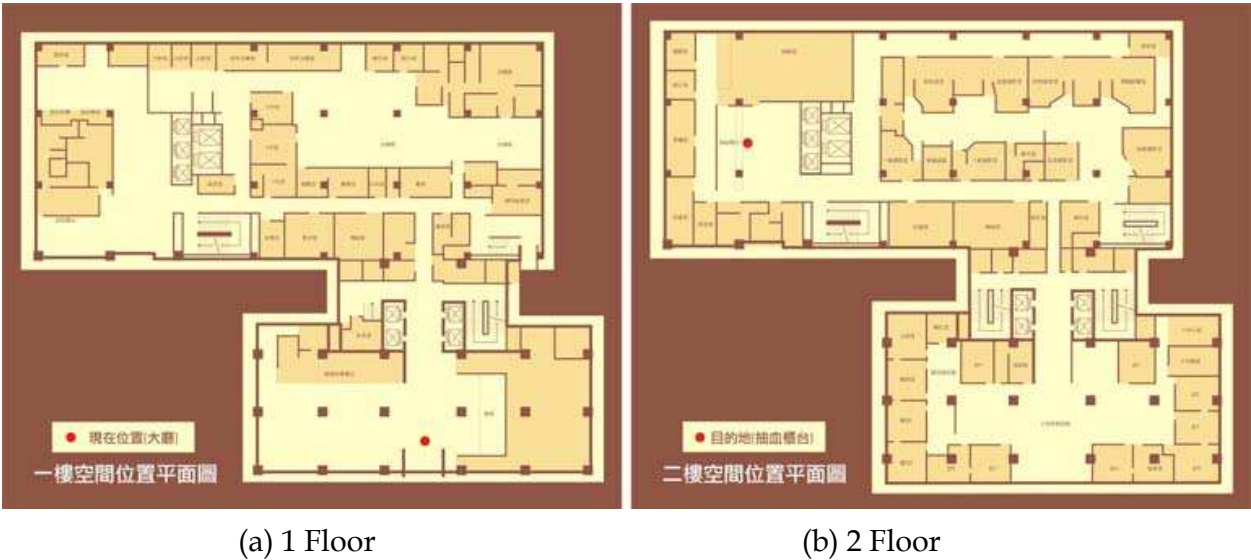

Fig. 1. Simulation workstation

(a) 1 Floor   (b) 2 Floor

Fig. 2. Map adopted in experiments

(a) Front Building   (b) Rear Building

Fig. 3. Map posted in the elevator lobby on the ground floor

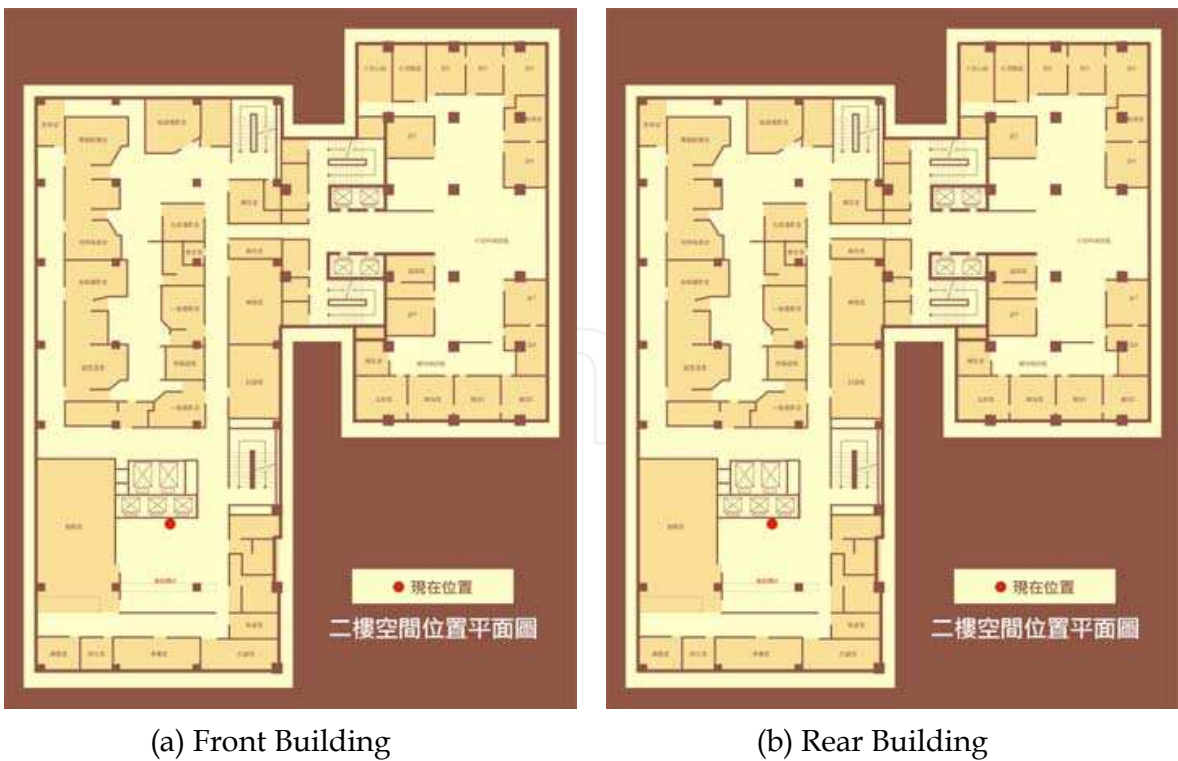(a) Front Building   (b) Rear Building

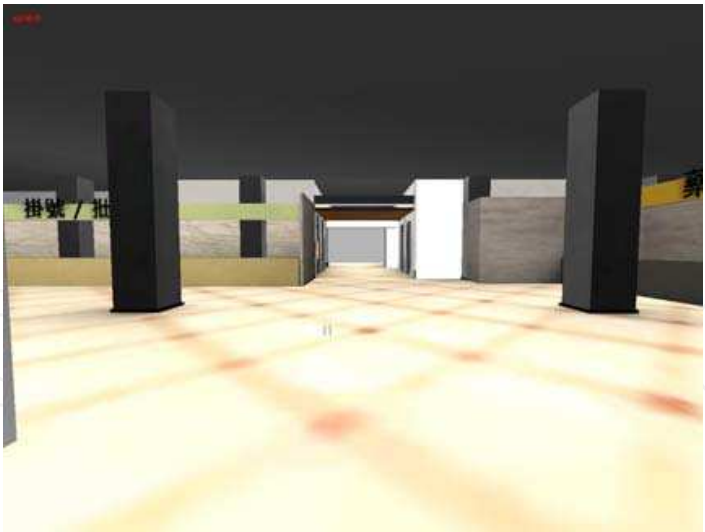Fig. 4. Map posted in the first floor elevator lobby

Fig. 5. Simulated node (starting point)

Fig. 6. Simulated node (ground floor elevators)

Fig. 7. Simulated node (#2 staircase on the ground floor)

Fig. 8. Simulated node (1st floor elevators)

Fig. 9. Simulated node (1st floor corridor)
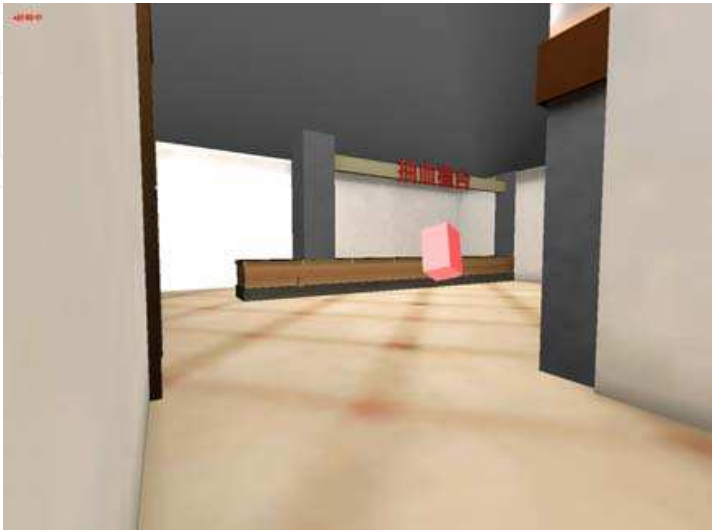
Fig. 10. Simulated node (destination)

2.5 Limitations

The core experiment conducted in this study took place in a virtual-simulated hospital, in which we sought to measure the relationship between orientation maps and reading cognition. The maps used in the experiment were the same as those in the hospital. As we focused on the correlation between orientation maps and reading cognition, several limitations arose in this study.

1. Prior to this study, a pilot study simulated by computer was carried out, based upon which we concluded that this work was of an exploratory nature. Also, since participants needed to be familiar with computers, the vast majority of subjects were between 20 and 39 years old. Most people outside of this age range were excluded.
2. In order to avoid any possible influence of the existence of other objects on spatial perception, there were no other objects in the simulated areas.
3. Since the simulation was done with a computer, it was hypothesized that the level of computer literacy would not affect the results of the experiment, and obtained data outliers were excluded from analysis.
4. It is difficult to control the actual psychological reaction of people in a hospital; consequently, in the VR experiment, the simulation was predetermined to take place under normal conditions, instead of under physical duress.
5. Map-reading time and way-finding time were measured and their means calculated separately. Measurement of map-reading time started off as soon as floor plans appeared, indicated by a red dot to signify the subject's current position; and stopped as soon as subjects reported understanding the maps. The measurement of way-finding time did not start until after subjects understood the maps, determined their current position, entered the virtual reality world, and started to move their mouse; that first mouse movement initiated measurement, which ceased as soon as the subjects arrived at their final intended destination.

3. Reading of orientation maps and analysis

3.1 Reading of orientation maps

When showing the orientation maps, two maps depicting the starting point (ground floor) and the destination (first floor) were displayed simultaneously on the same screen. Time measurement began as soon as the maps appeared on the screen and stopped when subjects realized where the starting point and destination were and completed their route planning. The mean time required to read the map was 49 seconds (Table 1, Fig. 11~13), but this was not the median time, as 60% of the subjects finished reading the maps in less than 49 seconds, 42% within 20 to 39 seconds.

Background	Map-reading time (s)	SD	Maximum time (s)	Minimum time (s)	Map-rereading time (s)
Entire group	49	26	150	16	14
Male	41	18	79	16	6
Female	57	32	150	18	8
Professional	32	13	63	16	6
Non-professional	63	27	150	29	8

Table 1. Map-reading time

The shortest distance between the starting and ending point, with a staircase in between, was 50 m, in accordance with the actual scale of the physical building. Under this circumstance, the time required for reading cognition was considerably less for men than for women (m:f = 1:1.39), and the map-reading time for women was 1.4 times that of men. The standard deviation for reading time was considerably narrower among men than among women, also indicating less variability in males. Comparing architecture-related professionals versus those without such a background, professionals exhibited superior reading map performance, as well as less variability; professionals used half the time required by non-professionals for map-reading (professionals:non-professionals = 1:1.97), indicating that architecture-related education enhanced their map reading skills. This suggests that there were certain technical symbols in the maps that delayed comprehension among those not already familiar with the field. If and how different subject backgrounds influenced reading cognition will be analyzed and reported later.

Subjects were informed prior to the experiment that they could reread floor plans (posted at certain locations, based on locations in the actual buildings) at the elevator lobbies if they became lost. Fourteen of 45 subjects (31%) chose to reread the floor plans during way-finding. One reread the maps twice, while others reread them once. Six of 23 males (26%) and 8 of 22 females (36%) reread the maps; 6 of 21 professionals (29%) and 8 of 24 non-professionals (33%) chose to reread the maps. In general, then, irrespective of gender or background, approximately 30% of the subjects decided to reread floor plans when they were lost during way-finding.
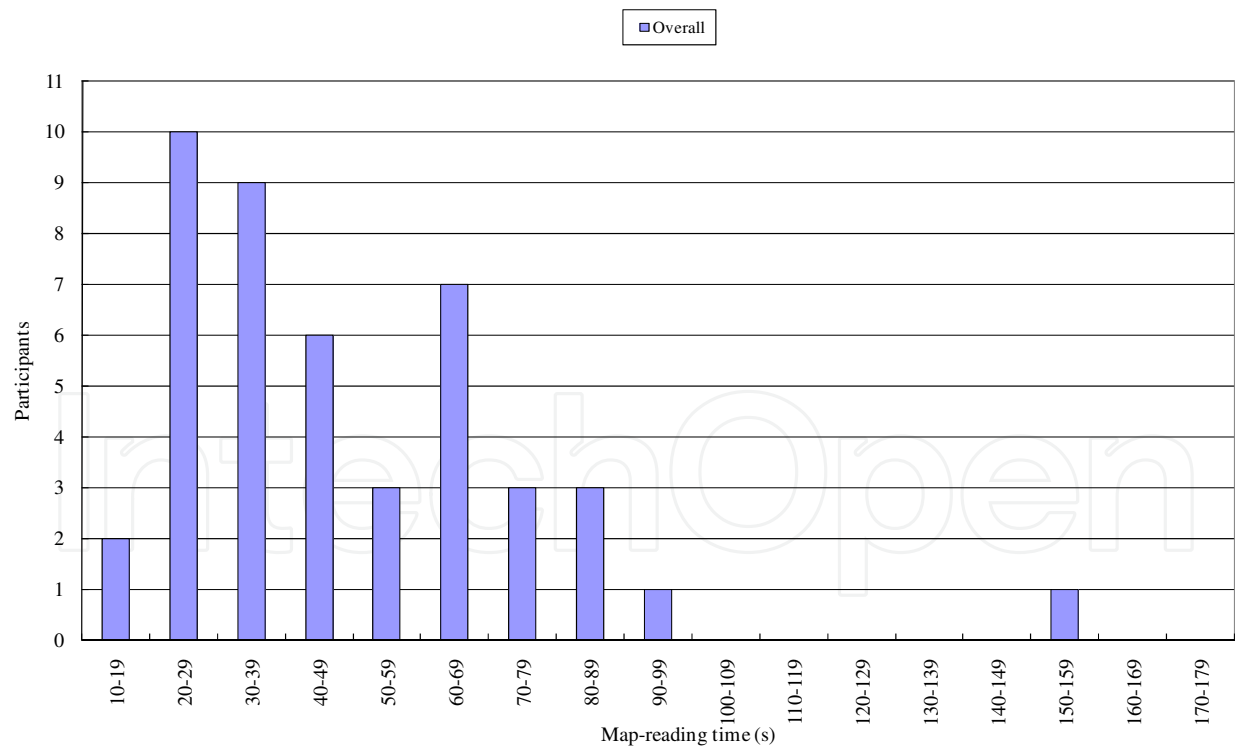

Fig. 11. Distribution of map-reading time of all subjects

In addition to the earlier report on differences in map-reading by gender and professional background, it is clear from Figures 12 and 13 that most men spent 20 to 49 seconds reading maps, whereas there was a greater range of time requirements for map-reading among

women. Architecture professionals generally spent 20-39 seconds map-reading, while there was a much greater range among non-professionals and the average in the latter group was more than 20 seconds longer.
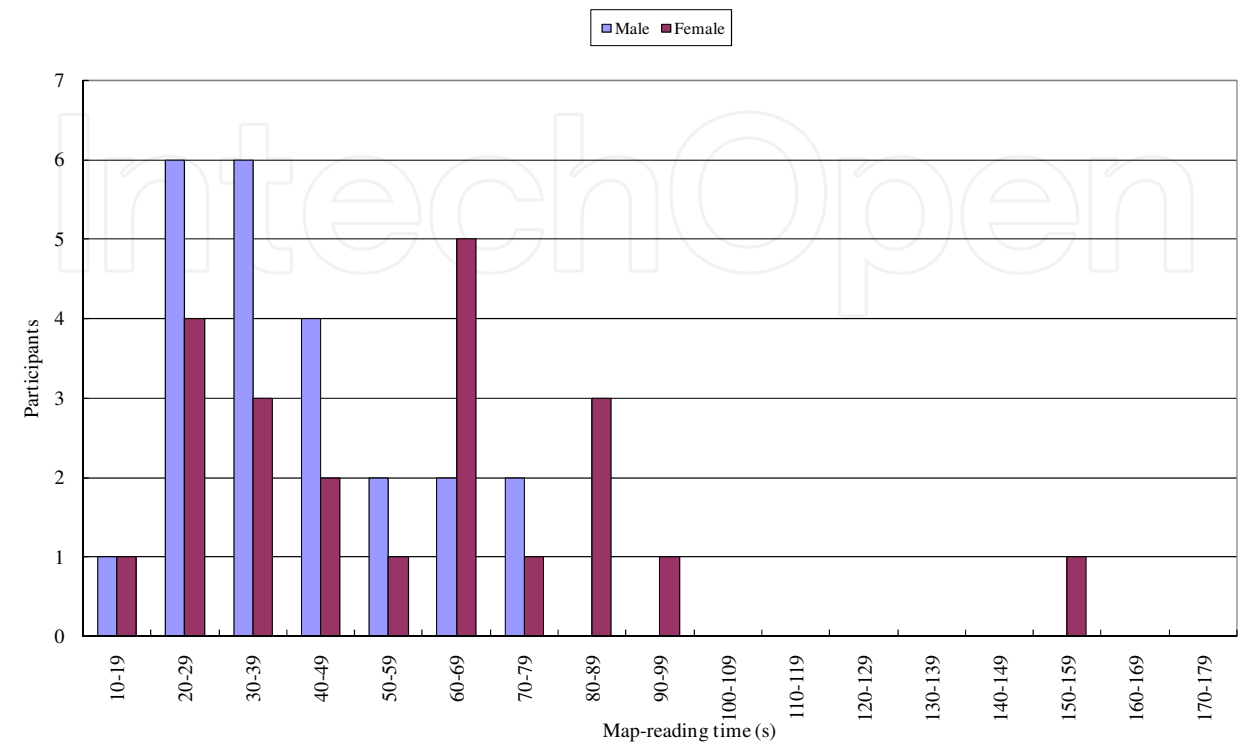

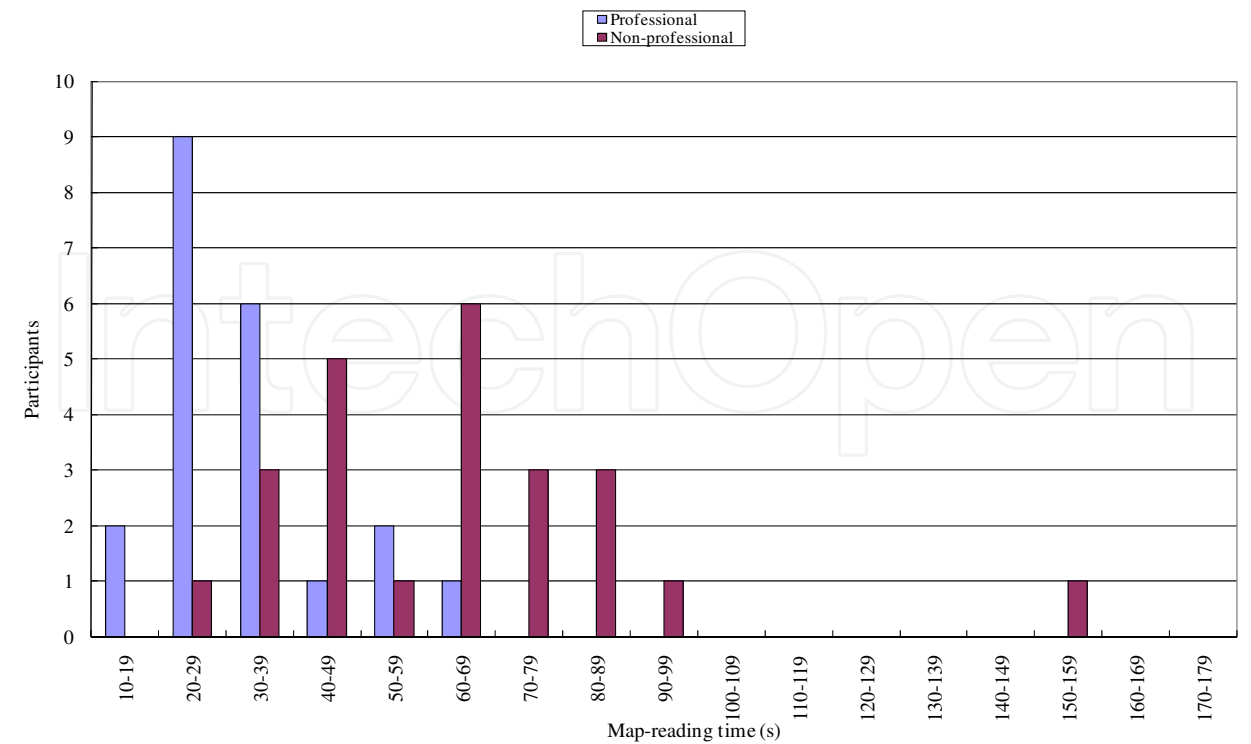Fig. 12. Distribution of map-reading time of males and females

Fig. 13. Distribution of map-reading time of professionals and non-professionals

3.2 Factors leading to differences in reading cognition

Preliminary analysis of the experimental data suggest that different backgrounds did influence outcomes; but whether or not these outcomes are statistically different between groups is yet to be verified. As a result, an attempt was made to determine which factors might contribute to significant differences in reading cognition in the public. The two demographic variables – gender and professional status - were processed and analyzed by means of t-tests for independent samples.

In the case of reading cognition, significant differences were apparent both for gender (p=0.030) and professional status (p=0.014), indicating that there were differences in reading cognition between men and women; and between those with versus those without architecture-related professional backgrounds. In other words, men and women, and professionals and non-professionals require different amounts of time to understand maps. Assessing the issue of professional status, it already has been shown that there are technical signs in maps that the public cannot comprehend easily; consequently, removing such symbols, at least to an appropriate extent, might be advantageous. Furthermore, 52% of male subjects had been in architecture-related professions, and 48% not; so it is obvious that having a professional background did not contribute to the difference between men and women, in terms of reading cognition. What truly makes a difference is the better reading cognition ability that is inherent in men. We concluded, therefore, that professionals and males have better map reading comprehension skills than non-professionals and females.

4. Simulation and analysis of way-finding

4.1 Time required for way-finding

In this instance, way-finding time was the time needed for the subject to proceed from the starting point on the ground floor to the end point on the first floor. The average time required across all subjects was 90 seconds, with a maximum of 174 seconds (a female non-professional) and a minimum of 53 seconds (a male professional). The maximum was almost three times the minimum (see Table 2). Moreover, the way-finding time for men was less than for women (m:f = 1:1.28) and the standard deviation for men was slightly less, as well. The times required by professionals and non-professionals, on the other hand, were pretty close (professionals: non-professionals = 1:1.08), as were the standard deviations. In the experimental design, the walking speed per second was set at 1 m, and the shortest walking distance was 50 m, so the shortest time path could not possibly be less than 50 seconds. Generally speaking, the way-finding time needed was between 50 and 89 seconds (62% of all subjects), with a steady decline in the numbers of individuals requiring times greater than 90 seconds (see Figure 14). Based upon the 50-second minimum time requirement, the following observations can be made: (1) the way-finding time required by men was 1.6 times the reference time; women 2.0 times; professionals 1.7 times; and non-professionals 1.9 times. Standard deviations were the least for men, suggesting an overall consistency in way-finding skills in males, relative to females.

The overall distributions of times for professionals and non-professionals were quite similar, mostly falling between 60 and 69 seconds. After the 70th second, the numbers dropped steadily. Preliminary analysis showed that professionals were not as efficient and effective in way-finding as expected (see Figures 15 and 16).

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Background	Way-finding time (s)	SD	Maximum time (s)	Minimum time (s)
Entire group	90	33	174	53
Male	79	30	150	53
Female	101	32	174	58
Professional	86	31	155	53
Non-professional	93	34	174	58

Table 2. Way-finding time
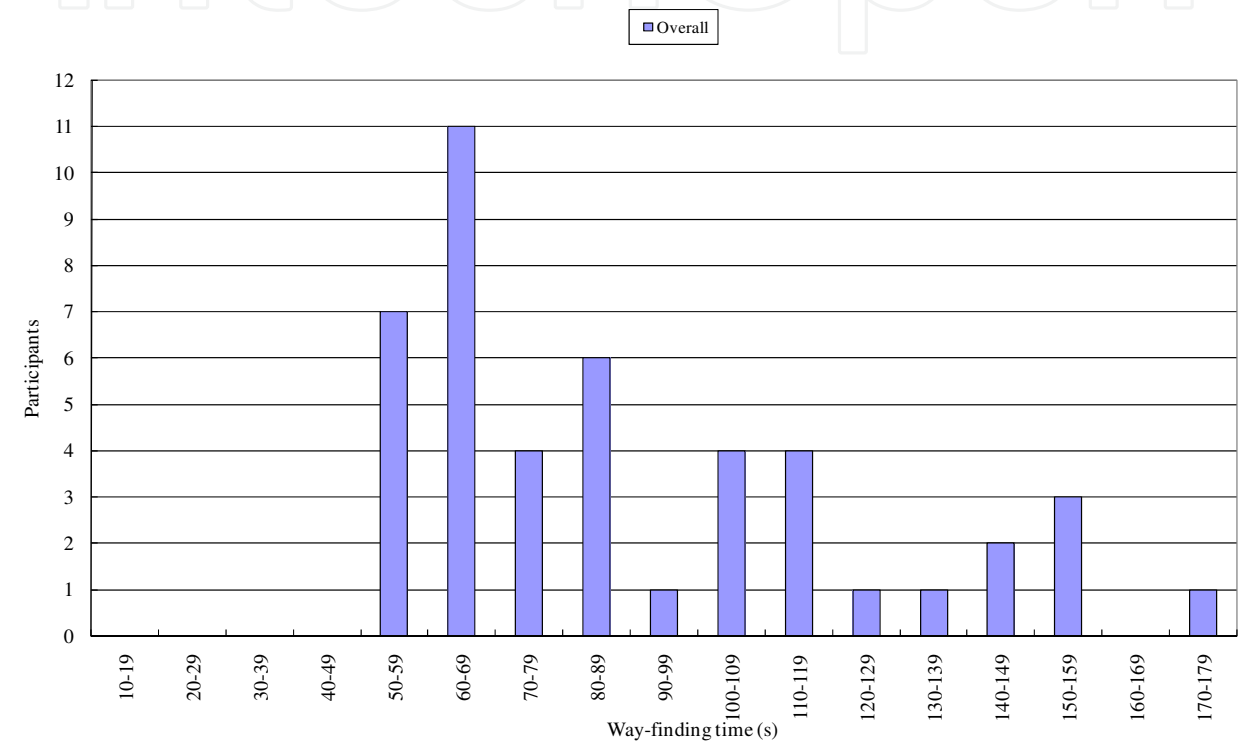
Fig. 14. Distribution of way-finding time of all subjects

4.2 Analysis of way-finding time

The results of way-finding time were analyzed using t-tests for independent samples, as was done for map-reading time. This analysis failed to identify any statistically significant differences by either gender (p=0.514) or professional status (p=0.542); in other words, gender and professional differences did not appear to influence way-finding time. What is noteworthy here is that professionals in the architecture field normally would be expected to be equipped with better spatial cognition and comprehension abilities, both of which should be conducive to way-finding, than those without such a background; but our findings argue against this. Architectural expertise did not facilitate the way-finding process, which suggests that difficulties exist in the transfer of knowledge from map-reading comprehension to the cognition of physical space. Whether or not other factors, like one's seniority or field of expertise (e.g., design versus engineering), cause these difficulties should be evaluated in future studies.
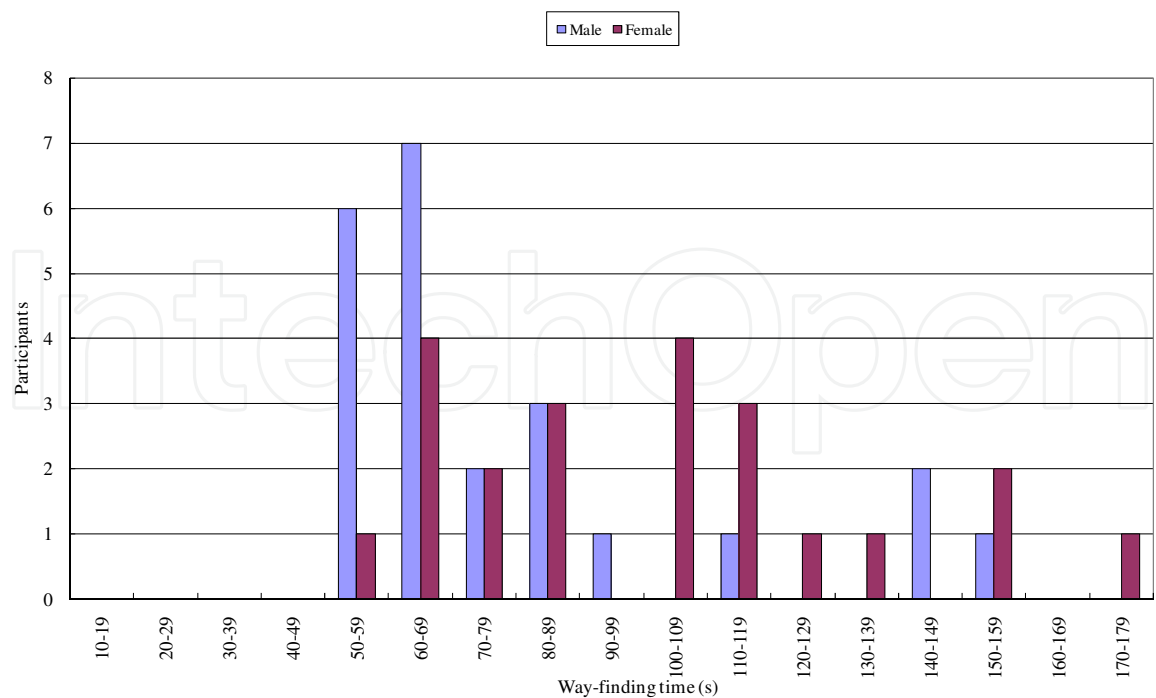
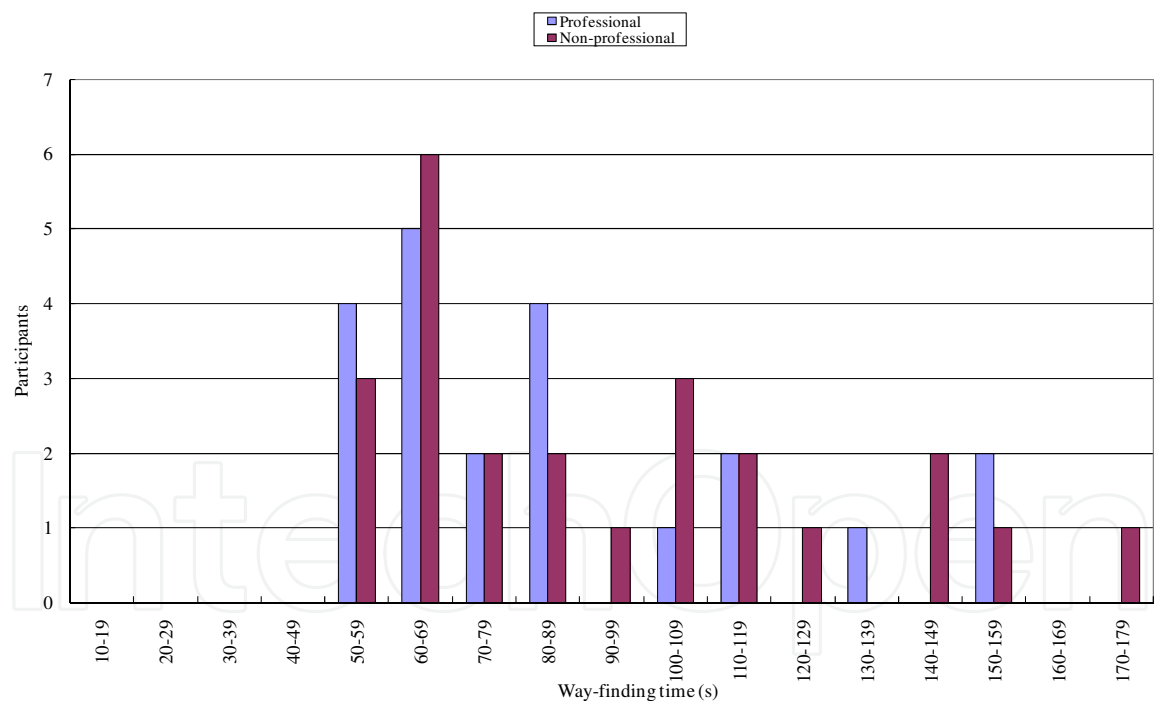Fig. 15. Distribution of way-finding time of males and females

Fig. 16. Distribution of way-finding time of professionals and non-professionals

5. Correlation between cognition and behavior

5.1 Correlation between map-reading and way-finding

This section will discuss map-reading and way-finding, and issues related to the transfer of reading cognition to spatial perception, in particular. When discussing the correlation between map-reading and way-finding, demographic data should be analyzed first. In this study, there

are two binomial variables – gender, composed of males and females; and professional status, composed of those with versus those without expertise in the architectural field (see Table 3 for details). The purpose of conducting t-tests was to determine whether different demographic backgrounds result in correlation between or differences in map-reading and way-finding. Results indicate that among males (p=0.010) and non-professionals (p=0.008), map-reading time and way-finding time were correlated; conversely, among females (p=0.263) and professionals (p=0.395), map-reading time and way-finding time were not correlated. A correlation coefficient (r) of 0.529, which we considered to be moderate degree of correlation, was identified for map-reading time and way-finding time among males; and much the same was observed in non-professionals. Furthermore, looking at the trend line for the entire group, it is apparent that the slope is positive, meaning that, as map-reading time increases, way-finding time does, as well (Fig. 17). For details related to the relationships between each variable and map-reading time and way-finding time, please refer to Figures 18 and 19.

Variables	Map-reading time (s)	Way-finding time(s)	Coefficient of correlation	Significance
Male (Map-reading vs. way-finding)	41	79	0.523	0.010*
Female (Map-reading vs. way-finding)	57	101	0.249	0.263
Professional (Map-reading vs. way-finding)	32	86	0.196	0.395
Non-professional (Map-reading vs. way-finding)	63	93	0.529	0.008*

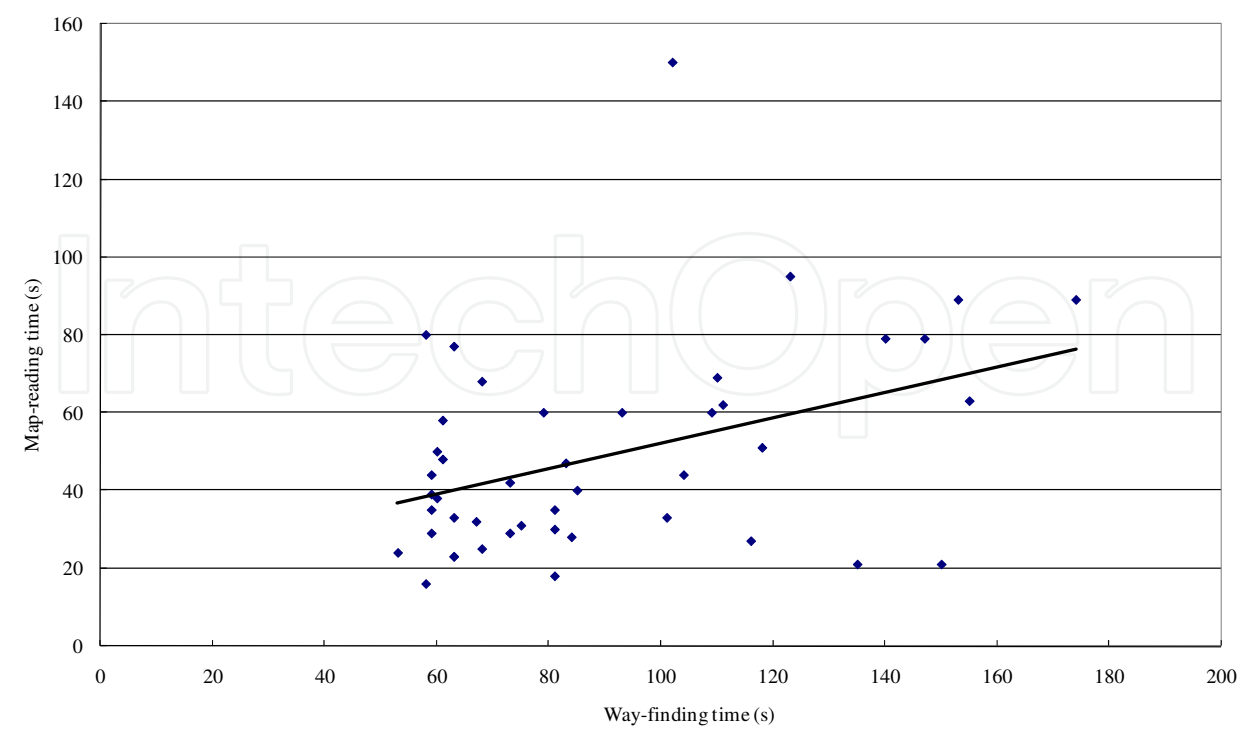Table 3. Correlation coefficient of map-reading and way-finding

Fig. 17. Correlation between map-reading by all subjects and way-finding
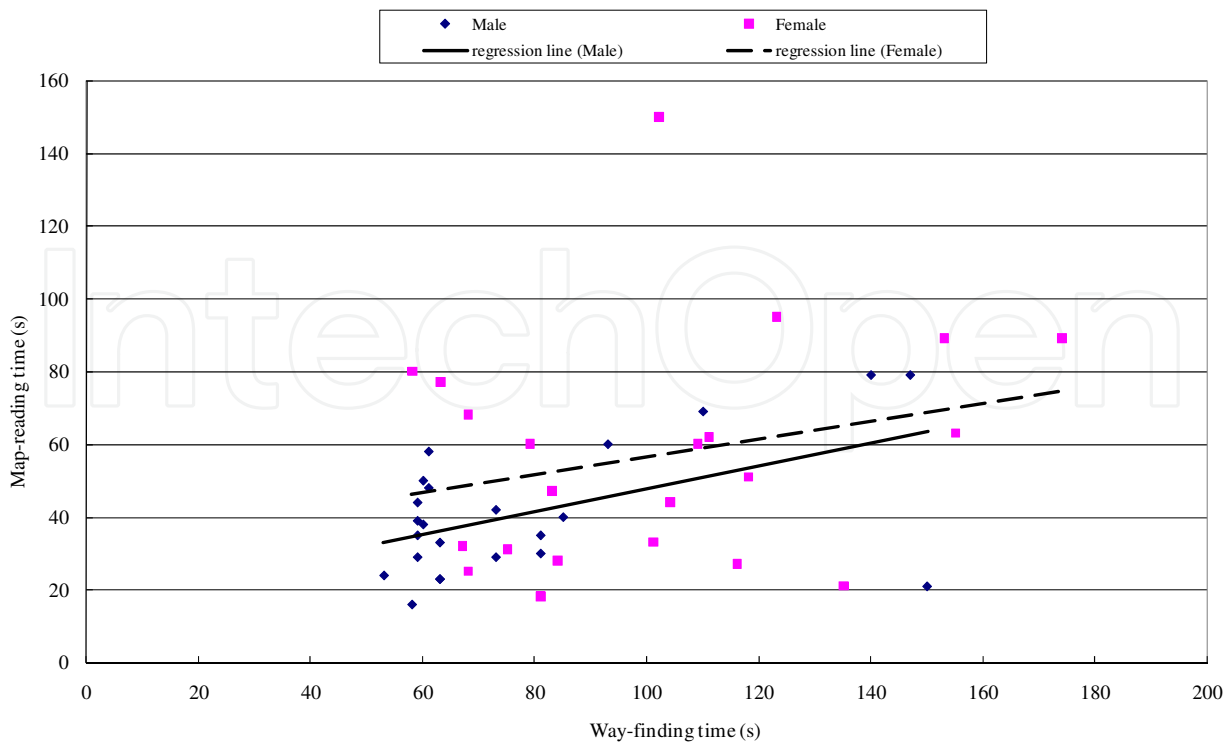
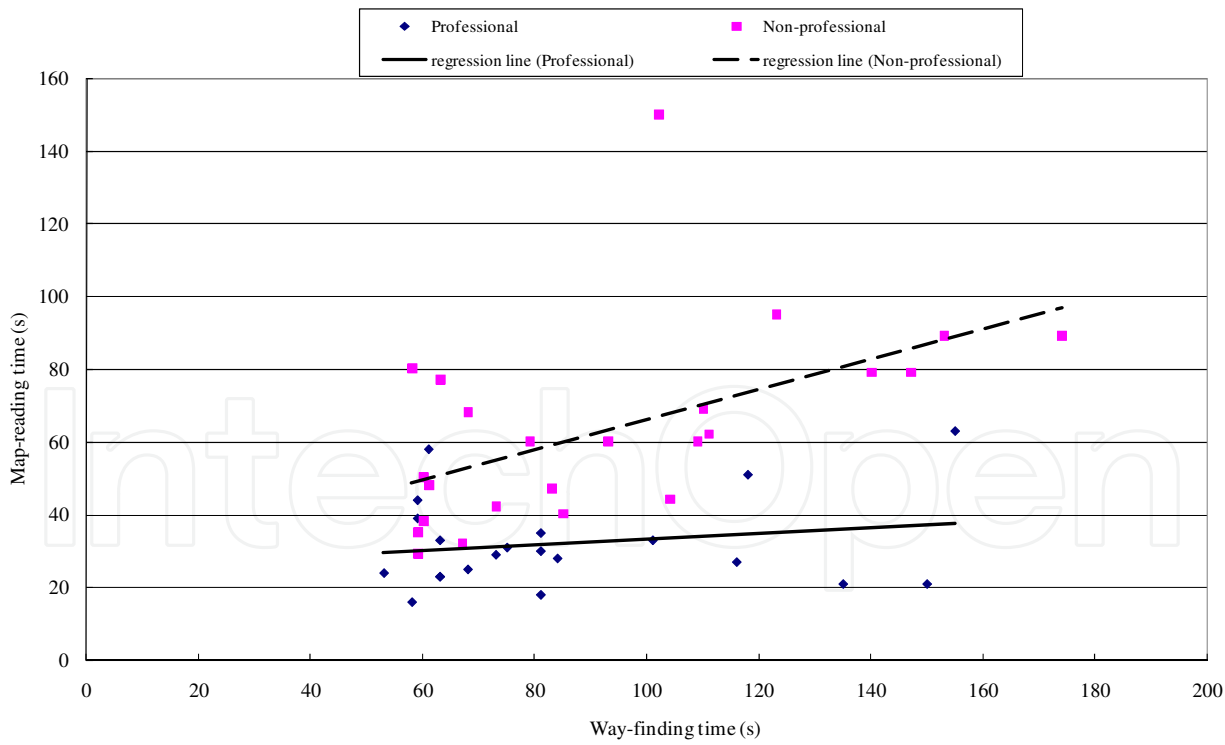Fig. 18. Correlation between map-reading by different genders and way-finding

Fig. 19. Correlation between map-reading by non-/professionals and way-finding

A moderate correlation between map-reading time and way-finding time was observed for men. That is, when map-reading time increased, so did way-finding time. This phenomenon also was found for non-professionals. Among women and professionals, no such correlation

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was identified, and this is worth investigating. During the experimental process, possibly because professionals were equipped with prior architectural knowledge, they finished reading their maps more quickly. One assumption is that, in their hurry to complete the map-reading task, the professional respondents overlooked relevant information on the maps, because they thought they understood the maps thoroughly. Once they entered the 3D virtual reality world, however, they became unable to apply their spatial knowledge from the maps to the physical space. Therefore, this author infers that education for architecture design professionals-to-be should be designed to enhance the students' 3D spatial perceptual abilities, so that consistency between their knowledge of maps and their physical space can be achieved.

To determine the relative influence of each variable on the total time needed by the entire subject group, multiple regression analysis was conducted. Here, *total time* refers to map-reading time plus way-finding time. The results are shown in Table 4. The p-values for both map-reading time and way-finding time were less than 0.05, indicating a statistically significance impact of each on the total time; however, beta coefficients reveal a greater influence of way-finding time (beta=0.659) than map-reading time (beta=0.532). Both are positively correlated with total time. All other variables were eliminated during the regression analysis procedure, indicating that whatever influence they exerted on total time was overshadowed by the influence of these two previously noted variables.

Variables	Standardized coefficient (Beta)	Significance
Gender	------	------
Professional background	------	------
Staircase choice	------	------
Map-rereading	------	------
Subjective sense of direction	------	------
Map-reading time	0.532	0.000*
Way-finding time	0.659	0.000*

Table 4. Correlation between variables and total time required

5.2 Analysis of subjective sense of direction, maps, and path time

Prior to the virtual reality experiment utilized in this study, subjects were asked to give their opinion about their sense of direction, using a five-point Likert scale (1 very good, 2 good, 3 fair, 4 bad, 5 very bad) to indicate their response. Among the 45 subjects, 4.4% chose very good, 40.0% good, 24.4% fair, 22.2% bad, and 8.9% very bad. In other words, roughly half of the subjects believed that they had at least a good sense of direction, and roughly one quarter felt their sense of direction was fair. Moreover, self perception of sense of direction was inversely correlated with way-finding time, such that those with a more positive subjective sense of direction spent less time on way-finding. What is more, the trend line shown in Figure 20 demonstrates a strong correlation in men, but a weak correlation in women.

Further, correlation analysis (Table 5) found that subjective sense of direction was correlated with map-reading time (p=0.006), but not way-finding time (p=0.234). In other words, participants with a positive perception of their sense of direction tended to perform better understanding maps after reading them, but they failed to exhibit the same degree of way-finding skill, suggesting that they had over-estimated their way-finding ability.
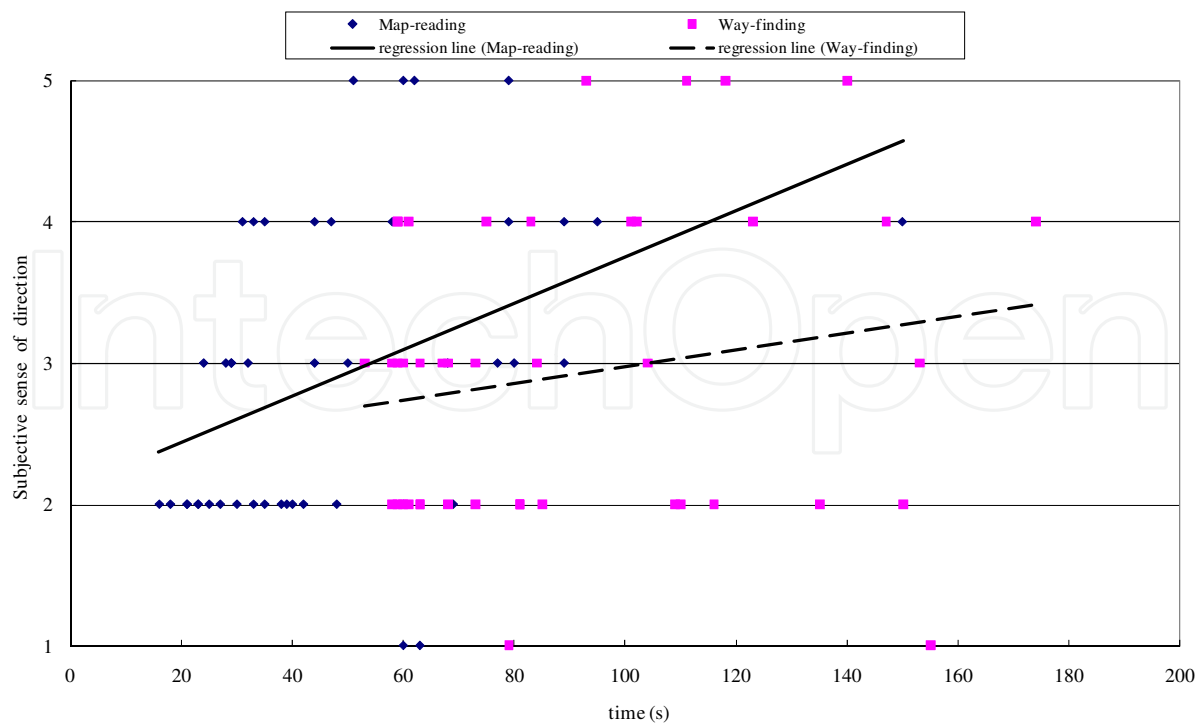
Fig. 20. Correlation among subjective sense of direction, maps, and path time

Variables	Coefficient of correlation	Significance
Subjective sense of direction vs. Map-reading	0.401	0.006*
Subjective sense of direction vs. Way-finding	0.181	0.234

Table 5. Correlation of subjective sense of direction

5.3 Analysis of choice of staircase during way-finding

In the virtual model floor plans employed in this study, there were four staircases, two (#1、#2) in the front building, and the other two (#3、#4) in the rear building. Their relative positions are shown in Figure 21. During the experiment, no clues as to which staircase leads to the first floor were provided. Subjects needed to make their own decisions based upon their understanding of the maps. As such, 13.3% of the subjects selected staircase #1, 57.8% #2, 22.2% #3, and 6.7% #4 (Table 6). Analyzing the data from the perspective of which staircases were nearest to the starting and finishing points of the intended path, #1 and #2 were closest to the starting point, and #3 closest to the final destination. Nevertheless, because of regulations related to map drawing, only half of staircase #1 was drawn, so it was not easily detected by subjects. Most subjects, therefore, selected staircases #2 and #3. This proves that clear and conspicuous representation of staircases exerts an influence on the reading and understanding of maps. It also shows that there is room for discussion as to whether the drawing of staircases in orientation maps should comply with the regulations set out by CNS 11567. For instance, if the depiction of staircase #1 was the same as for #2, our results might have been different. Additionally, approximately 40% of the subjects reported being unable to locate any staircases or having no idea where they were, suggesting that the representation of staircases in maps often is incomprehensible to the public. As a result, it may be necessary to appropriately adjust representations of staircases to reinforce staircase identification, or provide the lay public with training to establish a staircase schema.

Fig. 21 Relative position of staircases on floor plan

	#1 staircase (%)	#2 staircase (%)	#3 staircase (%)	#4 staircase (%)
Male	8.7	65.2	21.7	4.3
Female	18.2	50.0	22.7	9.1
Professional	14.3	61.9	14.3	9.5
Non-professional	12.5	54.2	29.2	4.2
Average	13.3	57.8	22.2	6.7

Table 6. Preference of staircase choice

Variables	Coefficient of correlation	Significance
Staircase choice vs. Map-reading	-0.044	0.772
Staircase choice vs. Way-finding	-0.029	0.849

Table 7. Correlation of staircase choices

We were not able to identify any significant correlations between staircase choice and either map-reading or way-finding. The choice of staircase did not affect way-finding performance (p=0.849); nor did it affect map-reading comprehension (p=0.772) (Table 7). Using t-tests to determine if gender and/or professional background influences stair choice, no significant influences were uncovered (gender: p=0.225; professional background: p=0.961). In other words, subjects generally selected the same staircases, irrespective of their gender or profession.

6. Conclusions

Tables and figures have to be made in high quality, which is suitable for reproduction and print, taking into account necessary size reduction. Photos have to be in high resolution. Tables and figures should be embedded in the text. A short descriptive title should appear under each table / figure / photo with a clear legend. (Table 1. Title, left justified / Fig. 1. Title, left justified). All units must be included.

This study employed a virtual reality (VR) approach to measure the time required both to read and comprehend a map, and to find one's way to a predetermined destination within a hospital, in an attempt to examine for differences in reading cognition and comprehension skills. Using VR platforms, simulations involving a variety of environments and signs/cues can be conducted effectively. In fact, virtual reality simulations have many incomparable advantages over on-site experiments, and play an important role in the spatial cognition of unfamiliar environments. Our findings were as follows.

6.1 Time required for reading cognition

The average map-reading time, across all subjects, was 49 seconds. Females were 39% slower at map-reading than their male counterparts; and those without a professional background in an architecture-related field were 97% slower (i.e., half as fast) than those with. This suggests that maps must have certain technical symbols that cannot be understood by those without some background in architecture, and that appropriate changes should be made to the representation in maps. Additionally, approximately 30% of subjects, irrespective of their professional backgrounds, decided to reread floor maps when they felt lost during way-finding.

6.2 Factors contributing to differences in reading cognition

It can be concluded from the t-test results that professionals and males have better map reading comprehension than non-professionals and females, the former finding again supporting the hypothesis that maps generally contain technical symbols that cannot be understood by most people and that should be considered for removal.

6.3 Results of way-finding

Overall, subjects averaged 90 seconds in finding their way through the VR simulation, but the range was broad, from a high of 174 seconds in a female non-professional, to a low of 53 seconds in a male professional. However, contrary to the results with map-reading, neither gender nor professional background appears to significantly influence way-finding time. This is surprising, given that those with professional backgrounds in an architecture-related field would be expected to have better spatial cognition and comprehension. One potential explanation for the lack of superiority of this group of individuals in way-finding is that they experienced difficulties in the transfer of knowledge derived from map reading comprehension to spatial cognition in the real world.

7. Acknowledgements

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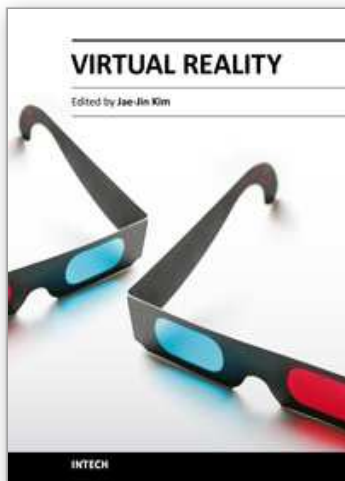
Virtual Reality

Edited by Prof. Jae-Jin Kim

Technological advancement in graphics and other human motion tracking hardware has promoted pushing "virtual reality" closer to "reality" and thus usage of virtual reality has been extended to various fields. The most typical fields for the application of virtual reality are medicine and engineering. The reviews in this book describe the latest virtual reality-related knowledge in these two fields such as: advanced human-computer interaction and virtual reality technologies, evaluation tools for cognition and behavior, medical and surgical treatment, neuroscience and neuro-rehabilitation, assistant tools for overcoming mental illnesses, educational and industrial uses In addition, the considerations for virtual worlds in human society are discussed. This book will serve as a state-of-the-art resource for researchers who are interested in developing a beneficial technology for human society.

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