A Study of the Indoor Walking Navigation System for Patients with Early-stage Alzheimer's Disease

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Abstract - We explored the effect and the difference between types of electronic map, paper map and colored lines guide on the wayfinding abilities of Alzheimer's disease (AD) patients. Fifty-six normal control (NC) subjects, nineteen mild cognitive impairment (MCI) patients and thirty patients with Alzheimer's disease (AD) were recruited to participate in this study. Based on a virtual maze with 3Dmax and an interface with Virtools, our results showed that the wayfinding abilities were worse in the AD group compared with the MCI group and normal aged participants. However, with the support of track-up map and colored lines guide, the AD group and MCI group had similar performance as to normal aged participants. Our study has provided insight to establish future electric navigation maps built for patients with cognition impairment.

Index Terms - Alzheimer's Disease, Walking Navigaiton Syetem, Wayfinding, Virtual Environment.

1. Introduction

Wayfinding is a dynamic activity in which people process the data or information they receive to predetermine destination through the cognitive abilities of the environment space [1]. In general, normal people can ultimately perform the wayfinding process successfully. However, for people with Alzheimer's disease, getting lost is the most serious problem to both themselves and their families. The prevalence rate of elderly dementia in developed countries is about 5-6% -- Alzheimer's being the most common type of dementia [2, 3, 4]. Related researches has indicated that there are about 89% of AD patients who had gotten lost in their familiar environment due to impaired ability of wayfinding [5]. McShane, et al. observed 104 AD patients every 4 months over a long time period. The record showed that there were 43 AD patients getting lost more than once in 5 years. Furthermore, 5 of the 43 AD patients were getting lost repetitively [6]. The road environment in Taiwan is highly complicated, which causes a high disorientation rate of AD patients. In addition, the impaired spatial cognitive ability and the hippocampus degradation that accompany AD seriously affects the process of wayfinding. Hippocampus being an important organ in the navigation task, its degeneracy or damage leads to the digression of AD patients [7], and causes serious spatial memory damage simultaneously [8]. Based on the above reasons, the early stage AD patients would have difficulties in accomplishing wayfinding tasks. Being unable to perform wayfinding successfully is an important characteristic of early stage AD patients. The quality of life would be improved and the cause of the disease would be better understood if the AD patients enhanced their wayfinding performances through appropriate navigation systems. Thus, the purpose of this study is to analyze wayfinding performances with different kinds of navigation systems used for AD patients. Furthermore, this study is also directed to develop a better navigation system for AD patients.

Common wayfinding aids provided through the visual sense are listed as the following: (1) Directional label, (2) Guideline label and (3) Identification label [9]. The straying of AD patients was caused by being unable to determine the path direction. In order to achieve direct and simple guidelines to minimize the information process of AD patients, four kinds of wayfinding aids were designed and examined to explore the most suitable method as the AD patients wayfinding aids in this study. They are: (1) North-up electric navigation map, (2) Trick-up electric navigation map, (3) Colored lines guide and (4) Paper map. Amount of the four wayfinding aids, the paper map used in the current study is a full view map, but both electric navigation maps are small-scale maps. Some related studies have indicated that the full view map lead an efficient guide of routes for routing decision [10]. Thus, many vehicle navigation maps present information with large-scale map. On the other hand, different studies indicate that comparison with the large-scale map (presenting more than 2 blocks) and small-scale map (presenting 1-2 blocks), vehicles have the shorter trip duration with the small-scale map [11].

Two common orientation instructions were north-up map (world-centered) and track-up map (ego-centered) [12]. There are no consistent conclusions on both orientations impacting on spatial cognition amount related studies. But most studies indicate that using north-up map decreases the difficulties in searching and recognizing specific landmark and increases better routing performance [13, 14]. On the other hand, the tracks demonstrate an advantage on route tracking and direction recognition [13].

In addition to the foregoing wayfinding guidelines tools, the current study takes a colored lines guide into consideration due to its prevalence and usefulness of the route directions in both unfamiliar and complex hospital space [14, 15]. Colored lines guide is an intuitive wayfinding assist mode and space users can just simply follow the lines without much pressure. As a result, this navigation method won't cause users too much of a burden.

Considering the insufficient research on the navigation system for AD patients, this study proposed a walking navigation system for dementia patients, carrying out the wayfinding performance when using electric map display methods with different orientations, paper map, and colored lines guide.

2. Methods

A. Participants

Fifty-six normal control (NC) subjects, nineteen mild cognitive impairment (MCI) patients and thirty patients with Alzheimer's disease (AD) were recruited to participate in this study. AD and MCI patients were recruited from a neurology outpatient clinic at National Taiwan University Hospital, Yun-Lin Branch. Normal control elderly participants were also recruited from Yunlin County. Informed consent forms were read and signed by each participant and the study was approved by the institutional review board ethics committee. AD and MCI patients underwent standardized examinations, including Mini-Mental Status Evaluation (MMSE) [16] and Clinical Dementia Rating (CDR) scale [17]. MCI was defined as a CDR of 0.5, and AD was defined as CDR of 1.0. The mean MMSE values of AD, MCI, and control groups were 15.08 ± 4.03, 19.42 ± 4.66, and 28.36 ± 1.89, respectively. Participants completing the experiment were each paid US$20.

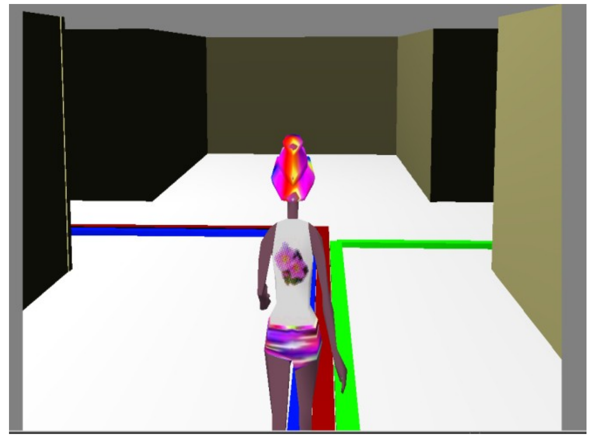
B. Apparatus

This study used a set of computer software to create an indoor virtual environment to simulating a walking situation in the real world. The indoor virtual environment was used to evaluate the interface design of the walking navigation systems. The experimental scene was created by 3D Studio Max 2011 software to construct a 3D scene model. The size of the scene is 100m x 50m, using Virtools 4.0 to set up an interactive interface. In this study, two 15-inch notebook computers were used to perform this experiment--a notebook computer rendered a 3D virtual environment; the other showed the map of the navigation system.

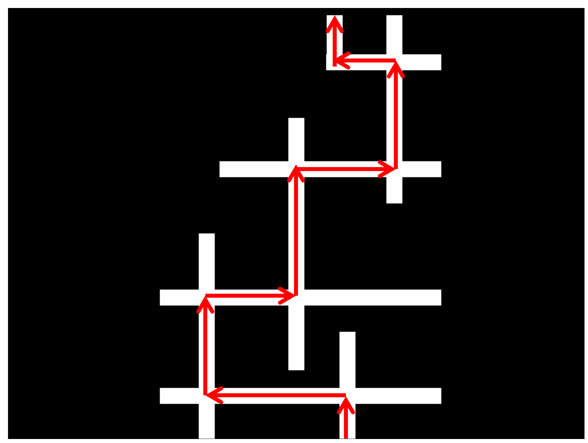
C. Experimental Design

Two factors were involved in this mixed-factorial experiment: subject groups (NC vs. MCI vs. AD; between-subjects) and navigation maps (north-up vs. track-up vs. colored lines guide vs. paper map；within-subjects). Each subject completed experiments in 4 different mazes. The complexity (i.e., number of turns) of all the mazes was the same.

The navigation map was divided into four types: 1) North-up map: the upward direction remained north consistently. It would not rotate with the pedestrian. The subject was required to identify the current direction by mental rotation, making it a world-centered reference frame; 2) Track-up map: the map would rotate while the pedestrian changed direction. The upward direction consistently retains the direction of travel. Pedestrians could determine the direction of the next turn without mental rotation, making it an egocentric reference frame; 3) Colored lines guide: the subject was instructed to follow one of the three colored lines on the floor to reach the destination (Fig. 1(a)); 4) Paper map: the whole route directions were depicted on the paper (Fig. 1 (b)).



(a)



(b)

Fig. 1 Examples of (a) colored lines guide, and (b) paper map with full of turn directions.

Two dependent variables were collected for this study: 1) Number of wrong turns; and 2) Performance time: the time the participant completed the wayfinding task.

D. Procedures

Before the start of the experiment, each participant was informed the purpose and the procedure of the study. Subjects were also told to stop at any time if they felt uncomfortable. A consent form was read and signed by each participant before he or she started the experiment.

First, subjects were instructed to preform one simulation exercise before the wayfinding test. They had to be able to give correct instructions and point out the path by gestures and words. We then verified that the subjects were fully aware of the method before the formal experiment. Subjects only needed to provide verbal instructions of "forward," "backward," "turn left," and "turn left" and gestured to the next direction without a need to control the keyboard. The experimenter operated the system instead of the subject in order to avoid possible errors due to motor difficulties in some subjects.

Each subject performed wayfinding tests in four different mazes, each with four different navigation systems, namely, track-up map, north-up map, colored lines guide and paper map. Each maze contained seven navigation decision points. Number of wrong turns and performance times were recorded. There was a 5-minute break between each experiment. The total experiment time was about 40 minutes. Subjects were paid after the completion of the experiment.

3. Results

A. *Performance Time*

The results of ANOVA test indicate that the navigation map types and subject groups had statistically significant main effects on performance time [F(3,255)=49.25, P<0.001; F(2,85)=66.00, P<0.001, respectively]. The track-up map (118.31s) and colored lines guide (122.63s) had the shortest performance time, followed by the north-up map (142.21s), and the paper map (169.40s). NC group (109.15s) had the shortest performance time, followed by MCI (132.98s) and AD (172.29s).

The two-way interactions were found for the performance time between the map types x subject groups, as shown in Table I [F(6,255)=16.53, P<0.001]. In the NC group, there is no significant difference in performance time between the four navigation map types (P=0.39). In the MCI group, the paper map had the longer performance time than north-up map, track-up map and colored lines guide [F(3,54)=10.41, P<0.001]. In the AD group, the track-up map and colored lines guide had the shorter performance time than the north-up map and paper map [F(3,36)=13.42, P<0.001]. Whatever the navigation map types, the NC group had the shortest performance time followed by MCI and AD.

Table I Wayfinding performances for the NC, MCI and AD groups under different navigation maps

	Performance time			Number of wrong turns		
	NC	MCI	AD	NC	MCI	AD
North-up map	109.54	129.72	187.37	0.25	1.90	2.85
Track-up map	107.86	115.78	131.30	0.00	0.16	0.31
Colored lines guide	107.05	119.25	141.60	0.02	0.11	0.31
Paper map	112.15	167.16	228.88	0.30	2.42	3.77

B. *Number of Wrong Turns*

The results of ANOVA test indicate that the navigation map types and subject groups had statistically significant main effects on number of wrong turns [F(3,255)=152.25, P<0.001; F(2,85)=76.03, P<0.001, respectively]. The track-up map (0.15) and colored lines guide (0.14) had less number of wrong turns, followed by north-up map (1.66), and paper map (2.17). NC group (.14) had the less number of wrong turns, followed by MCI (1.15) and AD (1.81).

The two-way interactions was were found for the performance time between the map types x subject groups, as shown in Table I [F(6,255)=41.00, P<0.001]. In the NC group, the track-up map and colored lines guide map had the less number of wrong turns than the north-up map and paper map [F(3,165)=6.47, P<0.001]. In the MCI group, the track-up map and colored lines guide had the less number of wrong turns than the north-up map and paper map [F(3,54)=28.15, P<0.001]. In the AD group, the track-up map and colored lines guide had the number of wrong turns, followed by the north-up map and paper map [F(3,36)=61.37, P<0.001]. Whatever the navigation map types, the NC group had the less number of wrong turns followed by MCI and AD.

4. Discussion

The performance time and number of wrong turns improved the most when subjects used the track-up map and colored lines guide. In all the systems we tested, the track-up map and colored lines guide showed better effect in facilitating wayfinding ability in all groups. According to some previous studies, AD impaired the ability to mentally rotate [18-20]. As a result, while using north-up maps, AD patients would miss the turning points or slow down because they couldn't mentally rotate the maps to unify with the maze [13]. Colored lines guide was a good design in developing electric maps for AD patients. Some previous studies found that colored lines guide has an effect on wayfinding performance in unfamiliar and complex hospital space [14]. The paper map was performed worst in all navigation maps, due to its full view, implying more information, heavier burden on attention and longer time needed to react. A possible interpretation would be that the AD patients with an impaired cognitive function were overloaded with too much information in the full view paper map.

5. Conclusion

Current navigation maps among related studies are designed generally for common people rather than for cognitive impaired patients. Our study proposed that track-up maps and colored lines guide could efficiently decrease number of wrong turns and performance time on wayfinding. Our result has provided insight to the development of future electric maps for cognitive impaired patients.

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