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Development and Verification of a VR Platform to Evaluate Wayfinding Abilities

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Abstract—**This study proposes a VR-based tool, named "Virtual City," to evaluate wayfinding abilities that are reported to decline with some cognition dysfunctions, such as dementia. This platform was designed according to cognition theories and took advantage of convenience of real-time recording by using VR techniques to make the evaluations less subjective and more accurate. Our previous study has shown the feasibility of using VR techniques to evaluate the sense of direction; we further use this newly developed tool to assess the effect of "screen type" and "reference landmark" on wayfinding performances. Experimental results show that subjects perform better with true-size 3D visual displays and reference landmarks, suggesting the factors that need to be considered for clinical application by using VR tools to detect cognition impairment in wayfinding.**

I. Introduction

NAVIGATION in a familiar or an unfamiliar environment is an essential ability to survive for human and other animal species. Animals need this ability to search for their food and find the way back to their shelters or avoid dangers. For humans, the network of our daily life is constructed by navigating betweens various destinations, such as offices, shops, and home. The wayfinding ability is performed so naturally for a healthy subject that it is not easy to be aware of. However, getting lost has been reported in clinical cases to associate with the impairment of related cognition functions [1]. Wayfinding behavior integrates the performance to find a way and the orientation behavior in a large-scale space [2]. In addition, recent approaches, using MR imaging with virtual-reality paradigms, have further demonstrated that the accomplishment of human navigation is contributed to by the functional interaction between the hippocampus and the retrosplenial cortex [3].

To date, the tools for diagnoses of the impairment of wayfinding ability still remain underdeveloped. Most of them rely on the descriptions of patients or their families on the basis of pencil and paper tests. However, due to the need of maintaining high caution and sophistic techniques to avoid potential biases during interrogation enquiry, some investigations manipulate the wayfinding tasks using pre-designed routes in a real environment to obtain a more objective assessment of the subject's behavior [4]. However, the real environment is hard to adapt to the experiment needs, and the inevitable noises from the surrounding could interfere with the participant's performance and thus may affect the accuracy of assessment.

Due to the advantages of accurate feedback, effectiveness, and nonspecific treatment effect, current cognitive rehabilitation tends to be accomplished by having patients work with personal computers [5–10]. In our previous study, we have developed a computer-aided platform, named Virtual Hospital (VH), to evaluate the sense of direction [11]. The development of the VH makes the evaluation of the sense of direction more convenient and accurate than the conventional way. The efficacy in differentiating the sense of direction between different genders shows the feasibility of the VH. Based on the previous success, we try to develop a new VR platform, named Virtual City (VC), for wayfinding ability evaluation.

Desktop monitors, due to their affordability and popularity, are commonly used to display the virtual scenes in recent neurological assessment applying VR technology. However, we doubt that their small size and the lack of the sense of depth for 3D objects can affect the cognition performance. In addition, clinical findings show that Alzheimer's patients tend to lose their way home despite being able to recognize the landmarks [1, 12]. That whether humans take advantage of landmarks to find their way has been an issue for exploring wayfinding behaviors. We therefore use the VC to test whether different types of visual display and the setting of landmarks can affect the user's performance. The results can provide an insight into the inherent problem for future studies to take care of.

II. Methods

A. System Configuration

The Virtual City was designed with a common local community style in Taiwan to give users a sense of familiarity during exploration. The system components and the corresponding development tools are summarized in Table I. Two types of visual displays, a 17" LCD and a 120" 3D projection display, were used for comparison and evaluation of the user performance with different types of display. The 3D projector rendered an immersive view when the viewer

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wore a pair of polarized glasses. A joystick was used to interact with the virtual scene. A VB program was developed to record the time and the occurrences of getting lost when the participant finished the task.

B. Experimental Design

1) Hypothesis: The experiment was designed under two hypotheses. First, the large screen can render a true-size scene; therefore, users should have better performance when using a 120” screen than a 17” LCD. Second, the test with presence of landmarks gives the users clues during exploration so as to enhance their performances.

TABLE I
TOOL KITS USED FOR SYSTEM DEVELOPMENT

Components	Tools
VR environment	*Discreet 3DS max v5.0 ; EON*
Interactive control	*Microsoft Visual Basic; EON*
Real-time recoding	*Microsoft Visual Basic*
Display	*17”LCD and 120”3D projector*
User interface	*Joystick*

2) Subject Selection: We have recruited 60 (30 males and 30 females) healthy subjects to participate in the experiment. They are college students and their study performance does not show any symptoms of cognitive impairment. The age of the subjects ranges from 19 to 22 years old. They are using computers regularly in their daily life; therefore all of them are familiar with manipulating the joystick to control the VH interface after a short practice session. All participants have signed the informed consent form.

3) Experimental Process: The test was carried out in a quiet room to avoid any interference. To assure the same initial condition for all the subjects, thus preventing any learning effect induced bias in the comparison of the test results, we only let the subject perform the VC for the first time in the test. At the beginning, the participant needed to login his/her personal information in the login window as shown in Fig. 1. Following that, a 2D map of the VC was given to reveal the community layout and the pre-defined route, as shown in Fig. 2. The participant was then required to explore the community according to the route.

4) Evaluation Parameters: Two parameters—the “duration” for completing the task and the “occurrence” of getting lost during exploration—can be measured automatically by this platform. In the VC, we setup a timer by using the computer system clock. It was initiated when the participant passed the main gate at the departure site, as shown in Fig. 3, and terminated when he/she arrived at the destination gate as shown in Fig. 4. We developed a VB program to detect the collision between the traveler and the gate in the virtual environment to initiate and terminate the timer. The route tracking was accomplished by numbering each route segment and recording the number according to the time sequence during exploration. By comparing the number sequence of the correct routes with that of the traveling routes, the occurrence of getting lost can be detected.

C. Comparative Studies

All participants were required to conduct the tasks with the same experimental process four times and under different situations, i.e., when using the 120” display with and without landmarks and when using the 17” LED with and without landmarks. Four landmarks—including a post booth, a fountain, a pavilion, and a trash tank—stood on the intersections of the pre-defined routes to give the clues for exploration. To avoid learning effects, each task was conducted at least one week after the previous one.

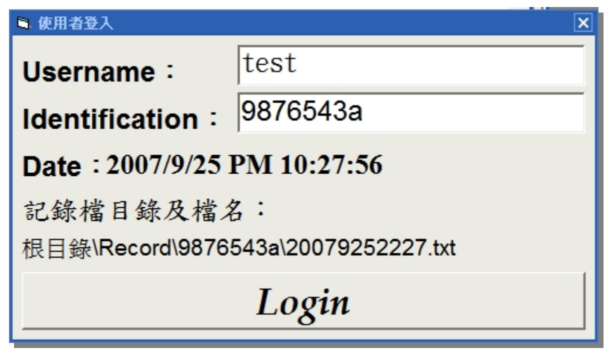

Fig. 1. The login widow will appear for ID input by the subject and data-linking when the Virtual City is initiated.

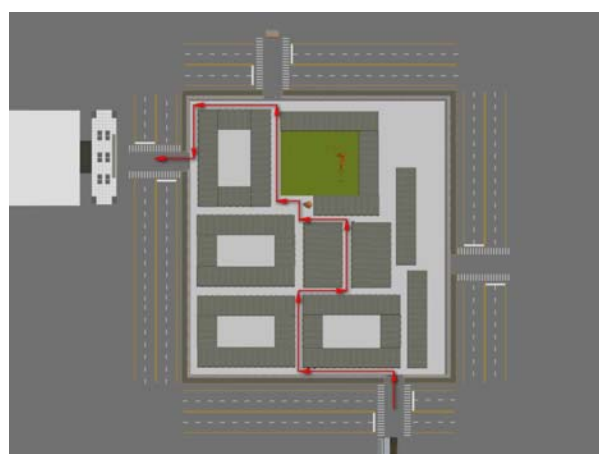

Fig. 2. The community outlet of the Virtual City contains several buildings, shown here as gray blocks. The red arrows indicate the pre-defined routes.

Fig. 3. The wayfinding task departs from the main gate of the Virtual City.

Fig. 4. The scene at the terminal gate of the wayfinding task

III. Results

The outlet of the Virtual City is shown in Fig. 2 and some shots of it—including the log-in window, the entrance, and the terminal—are demonstrated in Fig. 1, Fig. 3, and Fig. 4, respectively.

The results of the comparative studies are explained as follows.

1) Occurrences of Getting Lost: The number of participants who were getting lost during the tasks was counted in four situations individually. Table II summarizes the results. One can find that the number in the 17'' screen is more than five times that of the one with the 120'' display in the "no-landmark" case and double than that in the "with landmark" case. In the large 3D display, the number is equal in both cases, but in the small screen, the number in the "with landmark" case is less than half of that in the other.

2) Comparison with Display Types: The durations for finishing the tasks by using the 120" display and the 17" LED were measured for the 60 subjects. However, for an unbiased comparison in statistical analysis, we excluded the measures of the subjects who did not finish the task due to getting lost. A student's-t test was used to evaluate the differences of the results between the two groups. The results in Fig. 5 show significant differences associated with measures with different types of display. The time associated with the 120" 3D display is significantly lower than that with the 17" LED.

3) Comparison with/without Landmark: The durations for completing the task with and without the presence of landmarks were also measured for the 60 subjects. For the same reason, the statistical analysis excluded the measures of getting-lost subjects. The statistical results shown in Fig. 6 indicate that the duration for exploring the VR scene with landmark presence is significantly lower than that with landmark absence.

TABLE II
Number of Getting-lost Subjects

	no landmark	with landmark
17" LED screen	16	6
120'' 3D display	3	3

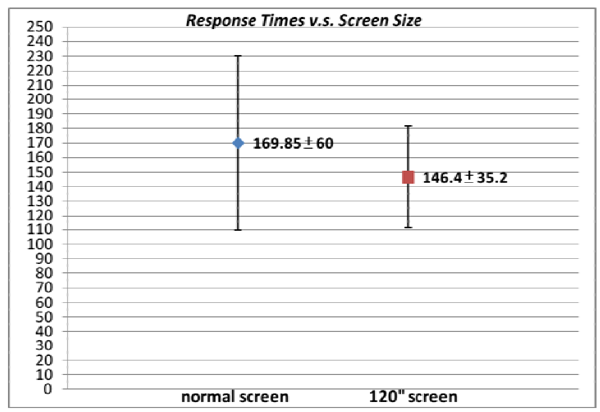

Fig. 5. The time taken for finishing exploration with different display sizes. The mean of the measures and their standard deviations are marked as the solid symbols and the error bars, respectively.

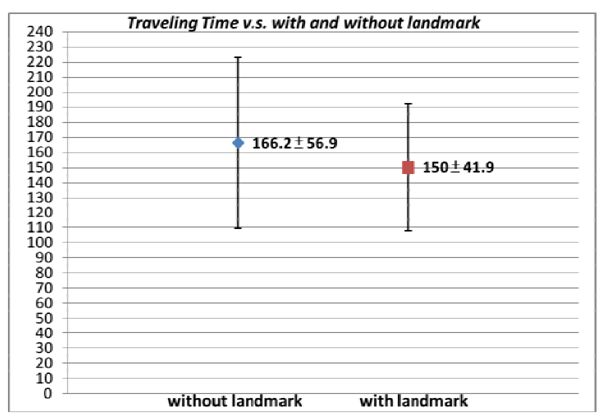

Fig. 6. The time taken for finishing exploration with and without the presence of landmarks.

IV. Discussion and Conclusion

Virtual reality with computer-aid technologies has recently received a great deal of attention in the field of cognition evaluations. In this study, we also developed a VR-based tool—named Virtual City—to evaluate wayfinding abilities that are reported to decline with some cognition dysfunctions, such as dementia.

However, less attention has been paid to the probable effects caused by different visual displays when applying the VR tools for cognition assessment. Hence, after completing the Virtual City platform, we further conducted comparative studies to evaluate the influences of visual display types and the landmark in the virtual environment on subjects' performances.

The results show that – participants have less tendency of getting lost and finding their way in a short period of time when using the 120" 3D display, suggesting that the true-size 3D display does really enhance the subjects' performances. In addition, the shorter time spent for exploration in the VC with the landmark presenting suggests that people intend to take the landmarks as the clues to find the way. However, the assistance of the landmarks for the subjects who are prone to getting lost is not so obvious when using the big 3D display.

Therefore, from these results, we may conclude that virtual reality techniques have great value in neurocognition assessment, but inconsistent types of displays and virtual environment setting can affect the assessment and induce some bias. Those factors should be considered for clinical application by using VR tools to detect cognition impairment.

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