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The Effects of Immersion on Visual Attention and Detection of Signals Performance for Virtual Reality Training Systems

Shiau-Feng Lin, Chiuhsiang Joe Lin, Rou-Wen Wang, Wei-Jung Shiang

***Abstract*—**The Virtual Reality (VR) is becoming increasingly important for business, education, and entertainment, therefore VR technology have been applied for training purposes in the areas of military, safety training and flying simulators. In particular, the superior and high reliability VR training system is very important in immersion. Manipulation training in immersive virtual environments is difficult partly because users must do without the hap contact with real objects they rely on in the real world to orient themselves and their manipulated.

In this paper, we create a convincing questionnaire of immersion and an experiment to assess the influence of immersion on performance in VR training system. The Immersion Questionnaire (IQ) included spatial immersion, Psychological immersion, and Sensory immersion. We show that users with a training system complete visual attention and detection of signals. Twenty subjects were allocated to a factorial design consisting of two different VR systems (Desktop VR and Projector VR). The results indicated that different VR representation methods significantly affected the participants' Immersion dimensions.

***Keywords*—**Virtual Reality, Training, Immersion, Visual Attention, Visual Detection

I. Introduction

RECENT recent advancement in Virtual Reality (VR) technology has made possible the human user high sense of immersion in interacting with the VR environment. VR is an interactive and reactive technology; it allows users to interact and navigate with objects in the virtual environment. In particular, in recent years, the virtual reality technology advances very fast as well as the technology for e-learning environment. VR systems have been applied for education, training and entertainment purposes in the areas of medicine, military, architecture, safety training, flying simulators and video-games. The VR system is a visualization tool which can be used to help designers, to train maintenance personnel and to illustrate functions of an industrial plant.

The advantage of the virtual reality is that the people can be immersed in the simulated environment, often not feasible, due to cost, safety, or perceptual restrictions in the real environment. Furthermore, virtual reality technology is increasingly being recognized as a useful tool for the study, assessment and manipulation training.

The capacity of VR to create dynamic, immersive three-dimensional stimulus environments, in which all behavioral responding can be recorded, offers assessment and manipulation options that are not available using traditional assessment methods.

However operators of traditional training methods such as printed documentation, images, video-based information presentation and slide shows are often not sufficient enough to support engineers with the complicated operating system sequences involved in a maintenance task. Consequently traditional training there are some disadvantages such as increasing cost for equipment, experts are only available locally and training center in a specific location [1; 2]. It can be deduced that current research work on VR for maintenance is based on either immersive or augmented VR technology. However, due to high equipment cost, using a commercially available immersive or augmented virtual environment for maintenance is not practical [3]. Furthermore, by replacing the real world's view with a computer generated images that react to the position and the orientation of the user's motion would cause the side effect known as ''simulator sickness''. These negative factors hinder the industrial application of immersive and augmented VR system. Thus, alternatively, in many VR applications, many users prefer a desktop virtual environment due to its low cost and portability. Therefore development of VR and simulation techniques contributes to an accurate and immersive training environment for NPP operators.

The advanced computer interface has been applied to execute the operations and status-monitoring by the human-system interface (HSI) in the main control room (MCR) of the advanced nuclear power plants. Main control room is defined as a functional entity with an associated physical structure, where the operators carry out centralized control, monitoring and administrative responsibilities. Compared with the traditional analog interface, the HSI of the advanced NPP has been relatively improved in terms of automation. The NPP main control room designs have progressed through three generations in the last thirty years. One of the most significant changes in MCR designs in the last two decades has been the increasing use of computers in plant monitoring and control [4]. Information has been largely presented on computer driven displays. A control room that uses computer driven displays for information presentation and plant control, as opposed to using hardware components, is sometimes referred as a "soft" control room. Increased computerization has made it possible to provide an interactive human system interface (HSI) through video display units to monitor and control most

S. F. Lin is a Graduate student in Ph. D. program with the Department of Industrial Engineering, Chung-Yuan Christian University, 200, Chung Pei Rd., Chung-Li, Taiwan 32023, R.O.C. (phone:886-3-2654451;fax:886-3-2654499;e-mail: g9602411@cycu.edu.tw).

C. J. Lin Author is with the National Taiwan University of Science and Technology #43, Sec. 4, Keelung Rd., Da'an Dist., Taipei City, Taiwan 106, R.O.C. (e-mail: hsiang@cycu.edu.tw).

R.W. Wang Author is with the Chung-Yuan Christian University #200, Chung Pei Rd., Chung Li, Taiwan 32023, R.O.C. (phone: +866-3-2654451; e-mail: akane.ou@ gmail.com).

W. J. Shiang Author is with the Chung-Yuan Christian University #200, Chung Pei Rd., Chung Li, Taiwan 32023, R.O.C. (e-mail: wjs001@cycu.edu.tw)

operations [5]. Human operators in a hazardous and complex automated system are required to monitor a large number of information sources and to reach a decision relevant to achieving a system goal efficiently and safely [6; 7]. When everything works smoothly, human monitors are just spare parts, but when there is anything wrong, the subsequent diagnosing and decision tasks impose a large amount of mental workload and stress on the human operator during abnormal operating procedures. Therefore, training in superior and high reliability system is very important in accident prevention. In the control room of a nuclear reactor, the operators monitor the nuclear process, control the technological systems, recognize disturbances that affect safety systems and maintain the plant in safe conditions. Therefore, in the Main Control Room operators need a very high visual attention at the same time to detection for a lot of signals. The control room is a complex environment, where the tasks and actions of the operators change dynamically as a function of the interaction between operators and the human-system interfaces. The operators must have access to control devices, safety systems, alarm systems and procedures. By combining the aforementioned operator-training programs and the virtual environment for MCR, the operators are able to walk through the operator-training programs using a desktop VR system as training and learning medium. Main Control Room (MCR) training simulator based on VR is a more cost effective and efficient alternative to traditional simulator based training methods. The VR simulation for MCR training is a complex task. Since VR not only reinforces the visual presentation of the training materials but also provides ways to interact with the training system, it becomes more flexible and possibly more powerful in the training system. Within VR it is possible to systematically present cognitive tasks targeting attention performance beyond what are currently available using traditional methods [8]. In the MCR operators may use just one display to view the wide range of the real world displays. The field of view (FOV) will be different from the real MCR environment in which many displays exist for the operators to view. Thus operator's immersion and visual attention will be reduced. This is the problem of MCR virtual training compared with the traditional simulator based training systems. Therefore, improving the operator's visual attention and the detection of signals in VR training system is a very important issue.

To validate the effect of virtual environment for MCR training strategies on operating in the NPP, this present research adopted a within subject experimental design to develop different experimental based on two types of VR representation methods (Desktop VR and Projector VR)and measure operator performance on visual attention and detection of signals. The next section introduced the experimental design.

II. METHODS

This virtual reality training program is developed using VR technology. This needs to provide users with fully integrated into the virtual reality experience that needs through a variety of hardware support to complete. This training system hardware used ViewSonic PJD6251 3D projector and ViewSonic 19-inches LCD provide a graphical interface for monitoring the reactor system status. Software used Inventor 2010、Unity 3D、Cinema 4D 、Deep Exploration. And 3D modeling is created from importing NPP model as shown in Fig. 1 made by Inventor 2010 and inputting event by U3D studio. U3D is the basic development tool that allows users of all experience levels to build interactive 3D product content quickly and easily with no programming experience required. The training system contains Wide Display Panel(WDP)、Main Control Console (MCC) Shift Supervisor Console (SSC) as shown in Fig. 2. In this training program can test and verify the operator’s performance, the VR training program’s design at MCR Visual attention and Detection of signals performance was used as the test task. We focused on the VR training system is interactivity and flexibility, the operator requirement was to attention and detection of signals. The effect of display mode on operation performance in the NPP control room can be gathered. Then, we develop a questionnaire for the evaluation of the immersion effect of the virtual display of MCR. To investigate the effect of display mode on operation performance, an experiment was conducted using a within-subjects design with thirteen subjects participating in the simulated scenario. All of them participated in two types of display modes included desktop VR mode and projector VR mode. Each subject could execute his hitting actions using a mouse.

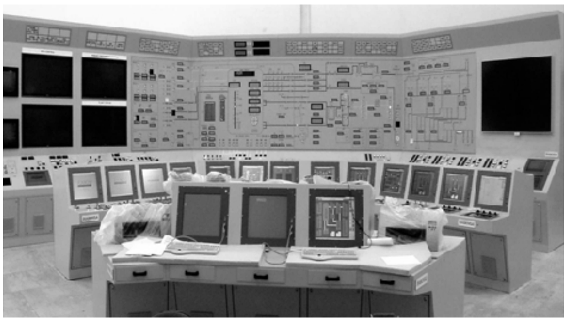

Fig. 1 Modern Main Control Room of the NPPs

Fig. 2 VR simulation for MCR

Dependent variables are: (1) Completion time. Participates were free to walk the MCR in the virtual scene and rapid discovery of fifteen signals, record the total time to complete the task. (2) Immersion Questionnaire, IQ. Immersion Questionnaire was assessed using the 3-D situational user immersion extent. The IQ is an experimentally validated, retrospective measure which requires participants to rate themselves on three dimensions that included spatial immersion, spatial immersion occurs when the player feels that he or she is really "there" and that a simulated world looks and feels "real". Psychological immersion, Psychological immersion occurs when a player confuses the game with real life. Sensory immersion, The experience of entering into the three-dimensional environment, and being intellectually stimulated by it. The player experiences a unity of time and space as the player fuses with the image medium, which affects impression and awareness. The ratings on each of the three dimensions are combined into a single IQ value.

A total of thirteen participants volunteered to participate in the study. All of them were graduate students and age ranged from 23 to 29 years. They were all reported good health and had no physical disability. No participant was familiar with NPP procedures, and it was assumed that they were all on the same level of procedure knowledge. Additionally, Reference [9] found that there was no significant difference between experts and novices, and between automatic reset and manual reset. Therefore, they can be regarded as representative participants. The experiment was conducted in a secluded and quiet room. The experimental procedure included nine steps as follow. (1) Give a document material used in the experiment and explain the experiment content and related special note. (2) Acquaint the simulated display of MCR (3) Participants practice the operation until skilled. (4) Test them navigation with the virtual system (5) Rest and wait for a formal test (6) After practicing, subject was required to monitor one kind of display mode and start to perform the detecting tasks in the formal experiment. (7) Record completion time (8) Fill out the immersion questionnaire. (9) Subject was required to monitor another display mode and perform the detecting tasks. (10) Finish the experiment and receive a reward as shown in Fig. 3. The subjects were told to try their best to perform the tasks in the required time and avoid any mistakes during the formal experiment. The entire experiment for a subject took 10-20 minutes.

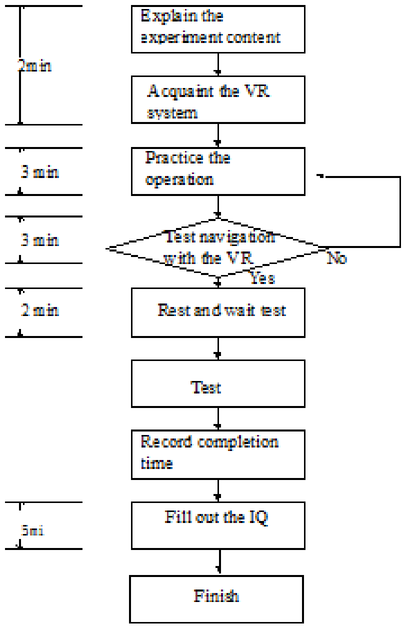

Fig. 3 Experimental procedure

III. EXPECTED RESULTS

The operating performance and Immersion Questionnaire of participants in the virtual reality displays on visual attention and detection of signals task was analyzed to distinguish the differences between Desktop VR and Projector VR modes by using the a one-way ANOVA analysis. The results are described as followed.

Table 1 shows the means and standard deviations for the overall sample (N=13). Desktop VR means reaction time is 391.07 second. Projector VR means reaction time is 189.52 second. Means of user immersion extent of VR simulation for MCR system is 68%. In table 2 shows The Projector VR completion time of participants in the VR training was lower than the Desktop VR training types. It shows that performance has significant influence on completion time (p=2.09E-06, $p<0.001$).

TABLE I
DESCRIPTIVE STATISTICS

Variable	Mean	Std.
Desktop VR	391.07	102.85
Projector VR	189.52	45.85
Immersion Questionnaire	68%	14%

TABLE II
ANOVA ANALYSIS OF DESKTOP VR AND PROJECTOR VR

Source of Variation	SS	df	MS	F	P-Value	Fcrit
Between Groups	264053.7	1	264053.7	38.4	2.09E-06	4.25
Within Groups	164856	24	6869.001			
Total	428909.7	25				

For both the participants with desktop VR and projector VR group, the introduction of immersion questionnaire into the detection task scenario resulted in more immersion with projector VR. In Fig 4 designate desktop VR means extent of immersion is 53%. Projector VR means extent of immersion is 83%.

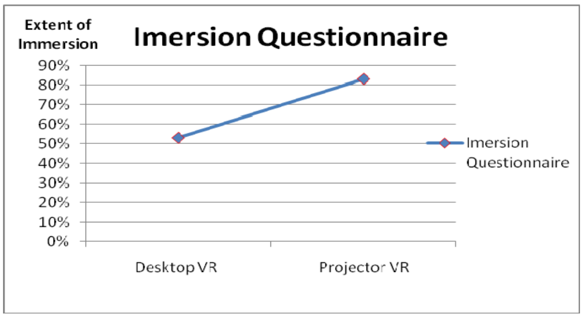

Fig. 4 Immersion Questionnaire

In Fig. 5 findings indicated significant relationships between total reaction time and immersion questionnaire the correlation coefficient (R=0.7303). These results demonstrate that there is a significant correlation between total reaction time and immersion questionnaire, that is, the participants in short time to complete the detection of signals task because they spend some degree of concentration and focused attention to locate the target Therefore, the participants relatively have higher immersion.

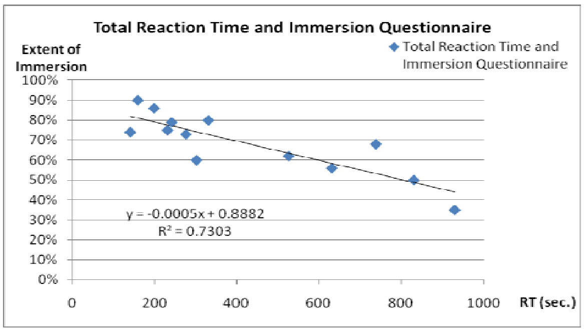

Fig. 5 Total Reaction Time and Immersion Questionnaire

From Fig 6, the results indicated that different three types of immersion questionnaire means of user immersion extent of VR simulation. User immersion extent of spatial immersion in the VR training was high than the psychological immersion and sensory immersion, spatial immersion mean user immersion extent 77%, psychological immersion mean user immersion extent 69%, sensory immersion mean user immersion extent 59%.

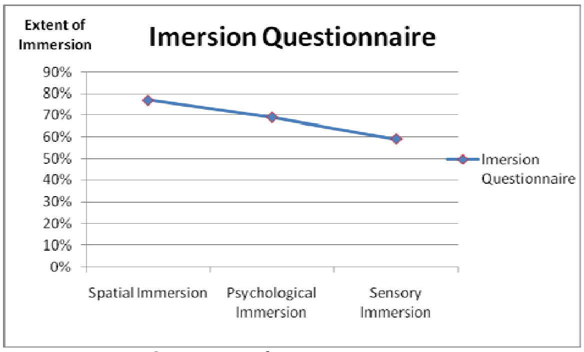

Fig. 6 Three types of immersion questionnaire

IV. CONCLUSIONS

The advanced NPPs adopt the modernized fully integrated digital design, the instrumentation and control (I&C) systems are digitized, and multiplexing network techniques and soft control are extensively adopted. Currently digital I&C system design are usually implemented at various vendor facilities. The VR simulation for MCR training claim that it can improve user performance, or giving an enhanced sense of "being there." We compared the performance of users searching for targets in desktop and projector VR the users consider projector VR can see the larger graphics, Therefore, increase the detection of signals performance. We found that subjects were also more focused on the detection of signals tasks. We randomly placed a target in the scene. For each search, we asked the user to either find the target was in the VR scene. Compared whits get lost, Participants in projector VR will not to get lost. In other words, projector VR to have better spatial knowledge in detection of signals tasks. Therefore, From the analytic results in this study, we strongly suggested that NPP Main Control Room virtual reality training can be conducted through projector VR in future.

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REFERENCES

[1] E. Bluemel, A. Hintze, T. Schulz, M. Schumann, and S. Stuering, Virtual environments for the training of maintenance and service tasks, Simulation Conference, 2003. Proceedings of the 2003 Winter, 2003, pp. 2001-2007 vol.2.
[2] V. Duffy, C. Washburn, P. Stringfellow, and A. Gramopadhye, Using Multimodal Technologies to Enhance Aviation Maintenance Inspection

Training, Digital Human Modeling, Springer Berlin / Heidelberg, 2007, pp. 1018-1026.

[3] K.I. Kashiwa, T. Mitani, T. Tezuka, and H. Yoshikawa, Development of machine-maintenance training system in virtual environment, Robot and Human Communication, 1995. RO-MAN'95 TOKYO, Proceedings., 4th IEEE International Workshop on, 1995, pp. 295-300.

[4] C.F. Chuang, and H.P. Chou, Investigation of potential operation issues of human-system interface in Lungmen Nuclear Power Project. Ieee Transactions on Nuclear Science 52 (2005) 1004-1008.

[5] W.F. Stubler, J.M. O'Hara, J.C. Higgins, and J. Kramer, Human-System Interface and Plant Modernization Process: Technical Basis and Human Factors Review Guidance [NUREG/CR-6637], DC: U.S. Nuclear Regulatory Commission, Washington, 2000.

[6] E. Hollnagel, and A. Bye, Principles for modelling function allocation. International Journal of Human-Computer Studies 52 (2000) 253-265.

[7] R. Parasuraman, T.B. Sheridan, and C.D. Wickens, A model for types and levels of human interaction with automation. Ieee Transactions on Systems Man and Cybernetics Part a-Systems and Humans 30 (2000) 286-297.

[8] A.A. Rizzo, T. Bowerly, J.G. Buckwalter, D. Klimchuk, R. Mitura, and T.D. Parsons, A virtual reality scenario for all seasons: The virtual classroom. Cns Spectrums 11 (2006) 35-44.

[9] M.B. Huey, and C.D. Wickens, Workload transition: Implications for individual and team performance, DC: National Academy Press, Washington, 1993.