Effects of Presence on Causing Cybersickness in the Elderly within a 3D Virtual Store

Cheng-Li Liu[1] and Shiaw-Tsyr Uang[2]

[1] Department of Management and Information Technology
Vanung University, Taoyuan, Taiwan
johnny@vnu.edu.tw
[2] Department of Industrial Engineering and Management
Minghsin University of Science & Technology, Hsinchu, Taiwan

Abstract. Along with elderly society's coming, computers with an internet connection used at home can provide this population a new channel to access to information and services, and can also be used to manage internet shopping tasks. One of the primary advantages of virtual environment (VE) technology applied in web shops is its ability to provide a 3D perspective to customers for more real sense on goods and shopping environment. The presence is a great appeal for the elderly experienced in the 3D virtual store. How to improve the presence of 3D virtual store is a challenge for the shopkeepers and programmers. But, whether it is easy to produce cybersickness in the elderly when the presence is improved, or not? The objectives of this study are to explore the effects of depth perception cues and display modes on presence and incidence of cybersickness in the elderly within a 3D virtual store. The results show that participants in high level depth perception cues with 3D monitor (with circular polarized glasses) will experience greater presence than other displays (HMD and TFT-LCD). However, a feeling of presence may add to the incidence of cybersickness($r = 0.671$, $p = 0.000$). Although the feeling of presence in TFT-LCD display is poor than 3D monitor and HMD, the symptoms of cybersickness are the slightest.

Keywords: 3D virtual stores, Elderly, Presence, Cybersickness, Depth perception cues, Stereopicture.

1 Introduction

1.1 General Introduction

With rapid development of internet, online shopping has become a way of locating oneself within today's culture based on what people purchase and how they use their purchases; indeed, it has become quite popular since its emergence on the internet. Along with elderly society's coming, many older adults (i.e., the "silver tsunami" generation) have problems performing daily tasks because of restricted mobility, lack of transportation, inconvenience, and fear of crime [4]. Computers with an internet connection used at home can provide this population a new channel to access to

J.A. Jacko (Ed.): Human-Computer Interaction, Part IV, HCII 2011, LNCS 6764, pp. 490–499, 2011.

information and services, and can also be used to manage internet shopping tasks. However, the traditional web shops introduce commodities only by 2D pictures and descriptive catalogue, which fall short in terms of reality and the interaction with goods. This kind design with poor reality and interaction will influence customers' real shopping experiences; and what is more, they minimize customers' desire to shop. Therefore, the elderly may find the barriers so great to prevent effective communication and shopping taking place [9]. Nowadays, such problems can be solved utilizing the technology of virtual environments (VEs). One of the primary advantages of VEs technology applied in web shops is its ability to provide a 3D perspective to customers for more real sense on goods and shopping environment. Therefore, we are deeply convinced that web 3D virtual store will be more and more popular in the future, and the older population would be growing rapidly worldwide and becoming an increasingly important demography in online shopping [10].

1.2 Presence and Depth Perception Cues of 3D Virtual Store

As we know the 3D virtual store is different from the common web store. The lifelike feeling of goods may hold a special attraction for the group of elderly. Therefore, it is a most important task for VE designers to develop an illusion of being "present" in a VE [24]. Several researchers have found that presence is generally regarded as a vital component of VEs for users to experience and interact with good sense in real time [17, 19]. Presence has been identified as being the defining characteristic, a design ideal or a desirable outcome of VE participation [23, 26]. Witmer (1998) defined presence as the subjective experience of being in one place or environment, even when one is physically situated in another [27]. Freeman et al. (1999) also described presence as the observer's subjective sensation of being there in a remote environment [5]. Lombard and Ditton (1997) proposed that presence is as a perceptual illusion of non-mediation involves continuous responses of the human sensory, cognitive and affective processing systems [15]. Therefore, a good presence of 3D virtual store would make users to immerse and involve in the shopping situation. The presence improving will be a challenge for shopkeepers and programmers [16].

There are some factors influence the degrees of presence within a VE. Perception of self-inclusion is a main factor [18]. Wickens et al. proposed that people would use a variety of depth perception cues to feel the shape and distance of objects within 3D environment [25]. Depth perception cues can be perceived via monocular depth cues, binocular depth cues and oculomotor cues. Monocular depth cues provide an equivalent percept to both eyes; the cues are equally effective whether using one or both eyes. Binocular cues, on the other hand, take advantage of both eyes by allowing each eye to receive slightly offset views of the same visual scene. Oculomotor cues occur via accommodation and convergence to involve combining visual and proprioceptive information from the eye to derive information related to distance.

Several researchers reported that monocular cues are the most important cues to depth in simulator displays [1, 6]. However, in the case of the near-view 3D display condition, the effect of the monocular accommodation increases with the blurring effect, so viewers can see unclear 3D images. Therefore, this is an inherent problem with good 3D image quality at the near-view. Additionally, binocular disparity is a binocular cue which creates the phenomenon of stereopsis and affected by the

stereoscopic properties of a display. Hale and Stanney found that a lack of binocular disparity may reduce one's perception of presence within a VE compared to that of normal sighted individuals. A small degree of binocular disparity creates stereopsis, a compelling impression of depth, as the two retinal images are fused together to form one single image [3]. Because stereopsis provides an enhanced perception of depth, stereoscopic displays (e.g. head mounted display (HMD), non-immersive (high resolution, stereographic ready monitors with circular polarized glasses) and auto-stereoscopic displays (defined as a 3D visual display that does not require viewing aids)) are thought to contribute to increased presence [8].

1.3 Cybersickness and Depth Perception Cues

Cybersickness is an illness for some users to exhibit symptoms that parallel symptoms of classical motion sickness both during and after the VE experience, in that it is most probably brought about by a sensory conflict between the three major spatial senses: the visual system, vestibular system, and (non-vestibular) proprioception [14, 20]. The main symptoms of cybersickness are eye strain, disorientation and nausea [13, 22]. Several researchers have found that 80% to 95% of users will experience some level of disturbance during exposure to a VE, with between 5% and 30% experiencing symptoms severe enough to discontinue exposure [21].

Some researchers found that there are some problems which have been associated with visual displays inducing cybersickness. For example, Howarth (1996) found that exposure to stereoscopic displays will increase symptoms of cybersickness (e.g. eye strain, blurred vision), the reason is oculomotor disturbance due to the mismatched oculomotor cues by such displays [7]. In addition individuals with low-stereovision may be unable to completely fuse these images together (i.e. presented with two different visual scenes), and lead to increased oculomotor disturbances [6]. These studies showed that the contributing factors of cybersickness are not only sensory conflict or postural instability but also depth perception cues.

1.4 Objectives

The technology used to create virtual environment has come a long way in providing immersive VE experiences. Through a combination of both hardware and software features, computer graphics systems allow the possibility of creating 3D virtual environments which can appear to be quite realistic and, in addition, can improve specific spatial task performance with good 3D image quality. When depth perception cues are improved with good 3D image quality and stereoscopic displays, however, whether the cybersickness for the elderly during exposure within a 3D virtual store stereoscopic displays will be easily caused or not? Therefore, the purpose of this study was to 1) understand clearly the effect of depth perception cues and display modes on presence and cybersickness in the elderly within a virtual store, 2) discuss the influence of presence that contribute to cybersickness.

2 Method

2.1 Participants

There were 60 people (average age of 65.3 years) selected to participate in the experiment. They were paid a nominal NTD500 as compensation for their time. All participants were fully informed and had signed a consent form. Some researchers found that repeated exposure to the same virtual environment with separation of less than seven days could significantly affect the levels of cybersickness which would induce participant's disorientation and nausea [13, 22]. Therefore, participants had not been exposed to the experimental VE in the previous 2 weeks.

2.2 Apparatus and the VE

The experimental environment was constructed by virtual developing software and presented on three types of displays: 3D monitor (with circular polarized glasses), HMD and 19" TFT-LCD display. The scene was designed as a retail store, which contained four subjective categories including stationeries, hand tools, cleaning articles and toiletries as shown in Figure 1. Stationeries and hand tools include

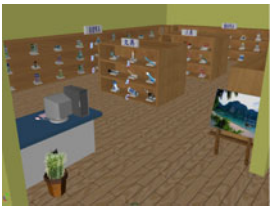
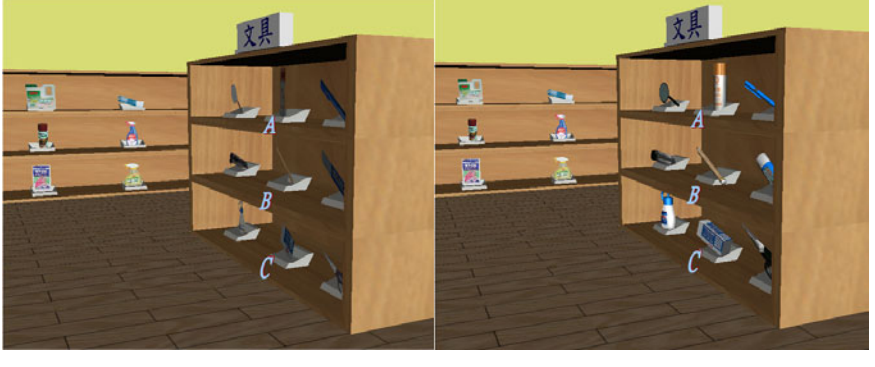


Fig. 1. A scene of the experimental 3D stationary store



(a) (b)

Fig. 2. A scene: (a) in low level depth cues with 2D images; (b) in high level depth cues with 3D stereopictures

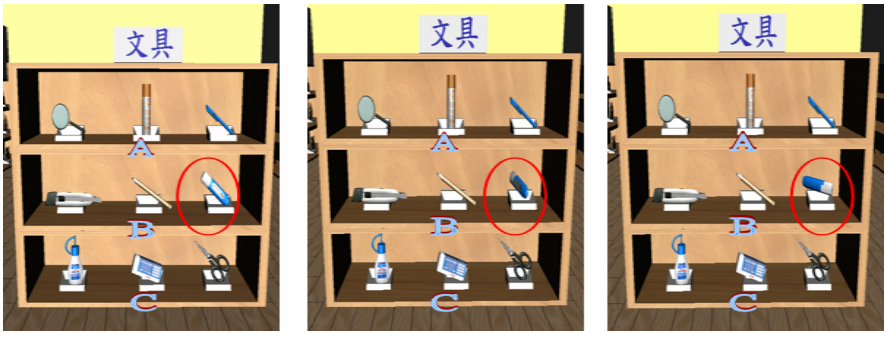


Fig. 3. The objects can be rotated along pitch and yaw axis in high level depth cues environment

eighteen goods exhibited respectively. Cleaning articles and toiletries include twenty seven goods exhibited respectively. Because this study was focused on the effect of presence in different depth perception cues, the scene was designed in two conditions: high and low level depth cues. Figure 2(a) shows a scene with low level depth cues, in which the goods are designed with 2D images. Figure 2(b) shows a scene with high level depth cues, in which the goods are designed with 3D stereopictures to appear to have good shape and depth. Additionally, the user can interact with objects by using the mouse. Figure 3 shows an object (a correction fluid) can be rotated along pitch and yaw axis for multiple viewpoints.

2.3 Experimental Design and Procedures

The study involved a 2 (level of depth cues: low and high) × 3 (mode of display: HMD, general display (22" TFT-LCD) and 3D monitor (Stereographic ready monitor with circular polarized glasses)), between-subjects experiment, resulting in a full-factorial design with six treatment conditions. Each participant was randomly assigned one of the six conditions to do the task of goods-finding. Therefore, there were ten participants randomly assigned to each one of the six conditions.

During the exposure period, participants were asked to search for and confirm some goods in the store. There were eight target goods need participants to search for, however, only six goods exhibited in the showroom, the others did not. When they found the target, s/he should write down the correct position on the check sheet (i.e. each showcase was numbered to let participant record number of position). If the participant found the target object did not exhibit in the showroom, s/he must remark "X" in the column of the object.

Before exposure, participants were asked to complete a Simulator Sickness Questionnaire (SSQ) documenting the severity levels of 16 sickness symptoms (Kennedy and Lane, 1993). SSQ is the most popular subjective measure for both simulator sickness and side effects experienced in VEs. If a participant reported any moderate symptom of discomfort or sickness in the pre-exposure SSQ, the participant was asked to rest for 10 min. prior to filling in a second pre-exposure SSQ. When all eight target goods had been found or confirmed not in the showroom, the experiment was completed. Finally, participants would be asked to complete Presence

Questionnaire (PQ) and SSQ. The PQ, devised to measure user presence within a virtual environment, consists of 32 questions regarding user interaction with 7-point scale rating (Lampton et al., 1994).

3 Results and Discussion

The initial statistical analysis revealed that the data set (presence scores and cybersickness scores with independent variables in different levels) was analyzed using the Shapiro-Wilk test to check the distribution of the sample. The results showed that the data set for each cell was normal distributed (P value > 0.05 in Shapiro-Wilk Test). Based on the results, an ANOVA analysis of presence scores and Cybersickness scores was performed. Based on the ANOVA results in Table 1and 2, it was apparent that the effects of depth perception cues and display modes are significant on presence and cybersickness symptoms in the elderly. More specifically, the following will be discussed.

3.1 Measures of Presence

Table 1 shows that depth perception cues in high level provided users sense of presence as having significantly higher than did in low level. It means that 3D stereopictures may have provided enough stereopsis and stereo acuity for users to closely check objects, examine objects from multiple viewpoints and well interact with the objects, thus users feel better presence than in 2D image of objects within the virtual store. In addition there is significant difference within display modes. Therefore, there is a need for further investigation into the different effects of display modes on presence. A Turkey's post-hoc test was used for pairwise comparison on display modes as shown in Table 3. The results show that the feeling of presence was the best on 3D monitor than others. It seems that when users browsed the virtual store

Table 1. ANOVA analysis of the effects of depth cues and display modes on presence scores

Sources		Means	SS	df	MS	F	P value
Depth cues	Low		14758.017	1	14758.017	72.244	.000*
	76.8						
	High						
	108.2						
Displays	TFT-LCD		11797.033	2	5898.517	28.875	.000*
	79.2						
	HMD						
	86.5						
	3D monitor	111.9					
Interaction			90.833	2	45.417	.222	.801
Error			11031.100	54	204.280		
Total			551237.000	60			

*p < 0.05 significance level

Table 2. ANOVA analysis of the effects of depth cues and displays on cybersickness scores

Sources		Means	SS	df	MS	F	P value
Depth cues	Low		784.238	1	784.238	26.419	.000*
	13.5						
	High						
	20.7						
Displays	TFT-LCD		534.793	2	267.396	9.008	.000*
	13.3						
	HMD						
	20.6						
	3D monitor	17.4					
Interaction			221.470	2	110.735	3.730	.030*
Error			1602.979	54	29.685		
Total			20645.698	60			

*p < 0.05 significance level

Table 3. Turkey's post-hoc tests for the effects of display modes on presence

(I) Display mode	(J) Display mode	Mean difference (I-J)	Std. Error	P value
HMD	TFT-LCD	7.250	4.520	.115
	3D monitor	-25.450*	4.520	.000
TFT-LCD	HMD	-7.250	4.520	.115
	3D monitor	-32.700*	4.520	.000
3D monitor	HMD	25.450*	4.520	.000
	TFT-LCD	32.700*	4.520	.000

*p < 0.05 significance level

with 3D monitor, the image will appear to have shape and depth and be, in a virtual sense, 3D. Then, the binocular disparity depth cues can be provided and benefit in making quick and accurate relative distance judgments may be proved. In advance, we found that through a combination of high level depth cues and 3D monitor as shown in Figure 4 (left side), phenomenon of stereopsis could be created easily, so the feeling of presence would be best for users. Although VEs were displayed via HMD that present separate images to create binocular disparity, the standard degree of binocular disparity was not sure to fit all users. So the average score of presence is fair. Additionally, browsing the virtual store in low level depth cues with TFT-LCD, the stereopsis could not created easily to limit depth perceiving, so the feel of presence would be poor.

3.2 Effects of Presence on Cybersickness

Participants' symptoms of cybersickness were evaluated by SSQ in the post-exposure. The results show that the effects of depth perception cues and display modes were significant. A Turkey's post-hoc test was used for pairwise comparison on display modes as shown in Table 4. It seems that no matter in low or high level depth cues, HMD would induce cybersickness easily. In addition the interaction effects between depth cues and display modes on cybersickness was significant, our concern becomes what mode of display with depth cues will result in significantly greater symptoms of cybersickness within a 3D virtual store. Figure 4 (right side) illustrates the interaction relationship between the effects of depth cues and display modes. It can be observed that the 3D monitor combined with low level depth perception cues would induce cybersickness slightly, but in high level depth perception cues participants suffered more severe cybersickness, even more serious than with HMD. It could be explained that the 3D virtual store with 3D monitor in high level depth perception cues would provide more in terms of interaction with objects, users might immerse in the VEs by

Table 4. Turkey's post-hoc tests for the effects of display modes on cybersickness

(I) Display mode	(J) Display mode	Mean difference (I-J)	Std. Error	P value
HMD	TFT-LCD	7.2930*	1.72293	.000
	3D monitor	3.1790	1.72293	.165
TFT-LCD	HMD	-7.2930*	1.72293	.000
	3D monitor	-4.1140	1.72293	.053
3D monitor	HMD	-3.1790	1.72293	.165
	TFT-LCD	4.1140	1.72293	.053

*p < 0.05 significance level

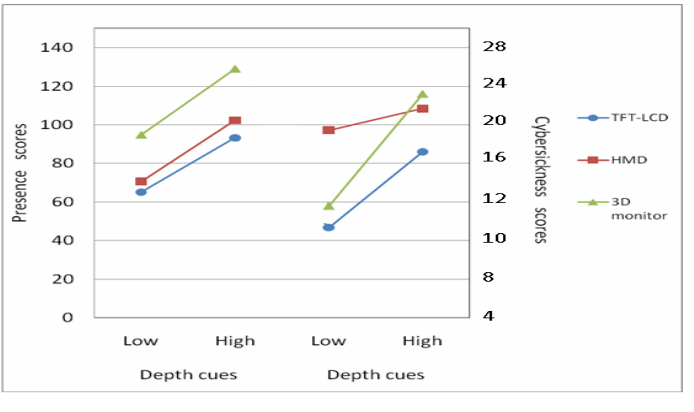


Fig. 4. Plots of mean scores of presence and cybersickness on depth cues for display modes (TFT-LCD, HMD and 3D monitor)

clicking and holding mouse button for moving, dragging or zooming in/out the goods and overall environment. Therefore, the symptoms of cybersickness are expected to occur for users due to speed and angle of the rotating scene and objects. Interestingly, in the same display instrument, there was a significant correlation between the experience of presence and incidence of sickness ($r = 0.671$, $p = 0.000$). It appears that the feeling presence adds to the incidence of cybersickness.

4 Conclusion

Virtual store with 3D images provides monocular depth cues to let older users experience good stereo acuity. The current study found that participants who have high level depth cues, and then do benefit from binocular disparity within a 3D monitor, were able to feel well presence. Although HMD could present separate images to create binocular disparity, the standard degree of binocular disparity was not sure to fit all users, so the feel of presence is fair. Additionally, there were significant differences found within the three display modes evaluated in this study in either reported sense of presence or cybersickness. Although the sense of presence in display with TFT-LCD was poor in either low or high level depth cues, the symptoms of cybersickness were the slightest. The older participants experienced presence so good in the high level depth perception cues of VE presented via a 3D monitor, but the symptoms of cybersickness was the most serious. In general, it is expected that exposure to 3D monitor will increase oculomotor disturbances due to the mismatched between the vection sensation and the vestibular cues under quick rotating speed, at a high angle of inclination for a prolonged period of exposure. In the future, it will be a step forward towards designing a warning system to detect improperly operating and prolonged exposure for combating cybersickness.

Acknowledgement. The authors would like to thank the National Science Council of the Republic of China for financially supporting this work under Contract No. 99-2221-E-238-014.

References

1 Cavoto, B.R., Cook, R.G.: The Contribution of Monocular Depth Cues to Scene Perception by Pigeons. Psychological Science 17, 628–634 (2006)
2 Cobb, S.V.G., Nichols, S., Ramsey, A., Wilson, J.R.: Virtual Reality-Induced Symptoms and Effects (VRISE). Presence: Teleoperators and Virtual Environments 8, 169–186 (1999)
3 Cutting, J.E.: How the eye measures reality and virtual reality. Behavior Research Method, Instruments, & Computers 29, 27–36 (1997)
4 Czaja, S., Lee, C.: Designing Computer Systems for Older Adults. The Human Computer Interaction Handbook 21, 413–427 (2003)
5 Freeman, J., Avons, S.E., Pearson, D.E., Ijsselsteijn, W.A.: Effects of sensory information and prior experience on direct subjective ratings of presence. Presence: Teleoperators and Virtual Environments 8, 1–13 (1999)

6 Hale, K.S., Stanney, K.S.: Effects of low stereo acuity on performance, presence and sickness within a virtual environment. Applied Ergonomics 37, 329–339 (2006)
7 Howarth, P.A.: Empirical studies of accommodation, convergence, and HMD use. In: Proceedings of the HOSO-Bunka Foundation Symposium, Tokyo (1996)
8 Ijsselsteijn, W., Ridder, H., Hamberg, R., Bouwhius, D., Freeman, J.: Perceived depth and the feeling of presence in 3DTV. Displays 18, 208–214 (1998)
9 Johnson, R., Kent, S.: In: Designing universal access: web-applications for the elderly and disabled, vol. 9, pp. 209–218 (2007)
10 Jones, S.: Generations online in 2009. Pew Internet & American Life Project Report (2009)
11 Kennedy, R.S., Lane, N.E., Berbaum, K.S., Lilienthal, M.G.: Simulator sickness questionnaire: an enhanced method for quantifying simulator sickness. International Journal Aviation Psychology 3, 203–220 (1993)
12 Lampton, D.R., Knerr, B.W., Goldberg, S.L., Bliss, J.P., Moshell, L.M., Blau, B.S.: The virtual environment performance assessment battery (VEPAB): development and evaluation. Army Research Institute, Orlando (1994)
13 Lathan, R.: Tutorial: a Brief Introduction to Simulation Sickness and Motion Programming. Real Time Graphics 9, 3–5 (2001)
14 LaViola, J.J.: A discussion of cybersickness in virtual environment. SIGCHI Bulletin 32, 47–56 (2000)
15 Lombard, M., Ditton, T.: At the heart of it all: the concept of presence. Journal of Computer Mediated Communication 3 (1997), http://jcmc.indiana.edu/vol3/issue2/lombard.html
16 Mikropoulos, T.A., Strouboulis, V.: Factors that influence presence in educational virtual environments. Cyberpsychol. Behav. 7, 582–591 (2004)
17 Nichols, S., Haldane, C., Wilson, J.R.: Measurement of presence and its consequences in virtual environments. International Journal of Human-Computer Studies 52, 471–491 (2000)
18 Sadowski, W., Stanney, K.M.: Presence in virtual environments. In: Stanney, K.M. (ed.) Handbook of Virtual Environments: Design, Implementation, and Applications, pp. 791–806. Lawrence Erlbaum Associates, Mahwah (2003)
19 Sheridan, T.B.: Musings on telepresence and virtual presence. Presence: Teleoperators and Virtual Environments 1, 120–125 (1992)
20 Spek, V.D.: The effect of cybersickness on the affective appraisal of virtual environments. Master's thesis, University of Utrecht (2007)
21 Stanney, K.M., Mourant, R.R., Kennedy, R.S.: Human factors issues in virtual environment: A review of the literature. Presence 7, 327–351 (1998)
22 Stanney, K.M.: Handbook of Virtual Environments. Earlbaum, New York (2002)
23 Steuer, J.: Defining virtual reality: dimensions determining telepresence. Journal of Communications 42, 73–93 (1992)
24 Sylaiou, S., Karoulis, A., Stavropoulos, Y., Patias, P.: Presence-centered assessment of virtual museums' technologies. Journal of Library and Information Technology 28, 55–62 (2008)
25 Wickens, C.D., Todd, S., Seidler, K.: Three-Dimensional Displays: Perception, Implementation, Applications, Crew System Ergonomics Information Analysis Center (1989)
26 Wilson, J.R.: Autonomy, interaction and presence. Presence: Teleoperators and Virtual Environments 1, 127–132 (1997)
27 Witmer, B.G., Singer, M.J.: Measuring presence in virtual environments: a presence questionnaire. Presence 7, 225–240 (1998)