Sense-of-presence in virtual and real environments showing similar content: questionnaire development and relationships among sense-of-presence, performance, and cybersickness

by

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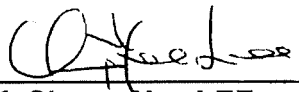

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Sense-of-presence in virtual and real environments showing similar content: questionnaire development and relationships among sense-of-presence, performance, and cybersickness

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Abstract

Sense-of-presence (SOP) is an important aspect in our perception of a physical environment and has been adopted as a standard measure of the quality of a virtual environment alongside with performance and cybersickness. The contribution of this thesis is two-fold: (i) it studies the presentation method of the current Presence Questionnaire (PQ, Singer and Witmer, 1996) with an aim to increase its ability to detect the significant differences among the rated SOP from participants expose to real and virtual environments showing similar audio and visual content; and (ii) it reports, for the first time, the relationships among SOP, performance, and cybersickness from participants exposed to virtual, telematic, and real environments of different field-of-views, image delays, use of stereo vision, use of 3D spatial audio, and image resolutions. Three experiments involving 216 participants were conducted. Results of the first experiment show that when using the PQ, participants were reluctant to select extreme positions (i.e. 1- or 7- rating) in a Likert scale even though these extreme ratings were the appropriate answers. In the second experiment, the PQ was presented according to techniques adopted from Cooper and Harper

(1969) and the percentages of participants who had inappropriately avoided selecting extreme values ratings values reduced significantly ($p<0.05$). In the third experiment, the PQ presented using the Cooper-Harper technique was used to study the relationships among SOP, performance, levels of cybersickness and excitement of participants exposed to a series of virtual, telematic and real environments showing similar content but with different combinations of field-of-views, image delays, use of stereo vision, use of 3D audio, and image resolutions. Gender effect was found in SOP, cybersickness and excitement ($p<0.05$) and no significant correlation between task performance and SOP was found. There was significantly positive correlation between SOP and excitement ($p<0.05$). Negative significant correlation between SOP and sickness was also found ($p<0.05$). Potential and actual applications of this research include game developments and virtual reality training.

CHAPTER 1

INTRODUCTION

1.1. What is Presence?

Presence is generally accepted as "the subjective feeling of existence within a given environment" (Heeter, 1992, Sheridan, 1992, Slater, Usoh, and Steed, 1994, Steuer 1992). In 1979. J.J. Gibson set the base of presence as a person's sense of self-existence. His idea about the individual's sense of self-existence is that it is completely determined by physical simulation and if there exists an environment which can support that person's actions, perception of self-existence must be veridical. His idea was later extended as presence which was defined as "tantamount to successfully supported action in the environment ... the environment is either real, teleoperation or virtual" (Zahorik, 1998). Later this philosophy and psychological idea of presence evolved into today's various presence definitions which involve real environment, teleoperation and virtual environment. The sense-of-presence (SOP) in different environments have different definitions but basically the same underlying meaning as the subjective "sense of being in a place". In a virtual environment, SOP is defined as "the subjective experience of being in one place or environment, even when one is physically situated in another" (Singer and Witmer, 1998) and Freeman et al. (1999) also defined virtual presence as " the observer's subjective sensation of "being there" in the remote environment". SOP in the virtual environment and teleoperation are defined as "sense of "being there" and "natural responses of human and environment to each other" (Sheridan, 1994, Schloerb, 1995, Welch *et al.*, 1996). From Johnson *et al.* (1999), virtual presence is defined as "the

experience of feeling physically present within the computer-generated environment". The discussion involving the definition of SOP is still on-going and the latest version is "presence is a psychological state or subjective perception in which even though part or all of the individual's current experience is generated by and /or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience. Except in the most extreme cases, the individual can indicate correctly that s/he is using the technology, but as "some level" and to "some degree" her/his perceptions overlook that knowledge and objects, events, entities, and environments are perceived as if the technology was not involved in the experience" (Lombard, 2000)

In this study, the meaning of presence is denoted as 'the subjective feeling of existence within a given environment". The meaning of virtual presence is the sense of "being there" in the environment depicted by the virtual environment and the level that the participants will be more responsive to the events in a virtual rather than a real environment.

1.2. Why do we need to measure sense-of-presence (SOP)?

As shown in section 1.1, there are many studies related to SOP. Why are people so interested in studying this? The main reason is the possibility of a positive relationship between participants' SOP and their task performance (Slater et al, 1997; Brystorm, et al, 1999; Nash, et. al, 2000). It is believed that when the SOP is higher, it indicates that a person pays a lot of attention to the environment and tasks at hand, and the higher the task performance will be. In addition, the impact of presence on sickness and emotion (Witmer

and Singer, 1998; Regenbrecht, et al., 1998) also raised interest in studying presence. The impact of presence, such as the negative relationship between presence and sickness that Witmer and Singer (1998) found, contributed to bringing virtual reality technology to real usage. Real applications, such as in psychotherapy in virtual environments, rely very much on presence as a connection between the similarity of behaviour in real and virtual environments. Regenbrecht and his colleagues (1998) addressed the fact that presence and fear of heights have a positive relationship. This may hint that higher measured presence causes stronger emotional responses in a virtual environment or the other way round.

1.3. How to measure subjective sense-of-presence (SOP)?

As it was expected that a positive relationship would exist between SOP and task performance, we wanted to know what level of SOP participants experienced. How do we know the level of SOP the participants experienced during exposure to the environments? Several methods are in use, such as Neurolinguistic programming (NLP) (Steed, A., Slater, M., Usoh, M., 1994), magnitude estimations (Snow and Williges, 1996) and individual questionnaires. NLP is a method that requires intensive analysis of the words that participants use in their responses to the questions about SOP. Through the analysis, experimenters will have an idea of which components, such as visual, audio or kinesthetic most influence the participants' experiences. However, due to the time consumed by analysis on procedure and the confusion among the writing style, wording and interpretation (Nash, et. al, 2000; Steed, A., Slater, M., Usoh, M., 1994), it is not commonly used.

Magnitude estimation is using the ratio method to estimate participant's subjective SOP. By asking participants to rate their SOP, experimenters can use their rating to form a regression model. This method may require experimenters to carefully choose participants to reach a reasonable level of reliability.

The most commonly used method to measure SOP is using questionnaires. The popularity of questionnaires was due to the easiness to use and easily created by the experimenters. Most of the questionnaires use a 7 or 10-point rating and participants choose the most suitable rating to describe their experience. A detailed review of the two most common questionnaires developed for measuring SOP can be found in Chapter 2.

1.4. Problem statement

1.4.1. The need of a presence questionnaire

It is expected that one day virtual environments will be as perfect as real environments – perfect virtual environments. In Sheridan (1994) it is mentioned that the "'perfect' tele or virtual environment is one which cannot be discriminated from a real and immediate environment". Therefore in order to prepare for this future need, a new set of questionnaires needs to be generated which can also measure SOP in real environments

Although there are different presence questionnaires which can be used in virtual environments, it is no easy task to find the "right" questionnaire on measuring SOP which can measure SOP across different environments. The problem is that current questionnaires used to measure SOP cannot

differentiate the between real and virtual environments. Usoh et. al., (2000) conducted a study on measuring SOP in real and virtual environments by applying the Presence Questionnaire (Witmer and Singer, 1996) and Usoh-Slater-Steed Questionnaire. The result was that neither questionnaire showed the significant differences between these 2 different environments and hence raised the question of whether the existing questionnaires can measure SOP across different environments. Other than this, a study from Johnson and Stewart II (1999) also shows that the Presence Questionnaire can not differentiate the SOP between various kinds of virtual environments and hence casts "doubt on accuracy on the Presence Questionnaire". Therefore there is a need to generate a set of questionnaires which can measure SOP across different environments in order to have an "accurate" measurement of presence.

1.4.2. Lack of one single experiment study on sense-of-presence covered range of variables from real to virtual

Another problem was that there was lack of a complete single study which covered sensory interface variables from real to virtual environments and related to sense-of-presence, sickness and performance. There was a study which was closest to this study was conducted by Snow (1996) and his study was quantifying the effects of 11 variables, which were field-of-view, display resolution, scene update rate, sound, textures, head-tracking, stereopsis, virtual personal risk, interactions, presence or absence of the other users and environment details, on SOP and performance using the sequential experimentation method. Although there were partially overlaps of the variables between this study and Snow (1996) study, the ranges of the

variables that chosen in Snow (1996) were limited to the virtual environments. In addition, Snow (1996) used the sequential experimentation method which consisted of 3 experiments, instead of one single experiment, to achieve the goal but failed. Therefore in this study, the effects of 6 sensory interface variables on SOP, performance and sickness would be investigated.

1.4.3. Relationship among sense of presence (SOP), performance and sickness has not been fully studied

There was a model proposed by Bystorm, Barfield and Hendrix (1999) which suggested the existence of the relationship among sense-of-presence (SOP), performance and sickness but the model was not verified yet. There were also other studies on relationship between sickness and SOP, such as in Nichols, et al. (2000) and Freeman, et al. (2000) but there was not a single study which investigates the relationship among SOP, performance and sickness.

1.5. Purpose of this research

In this study, the objectives are: (1) study relationship among sense-of-presence (SOP), sickness and performance in real, telematic and virtual environments within one single experiment and (2) Questionnaire developed to measure sense of presence in real, telematic and virtual environments. In order to archive Objective (1) which is to study the relationship among SOP, sickness and performance from real to virtual environments and solving the

problem listed in Section 1.4.1, a questionnaire was needed and this led to Objective (2).

1.6. Limitations and scope

1.6.1. Use of existing definition

The author of this study acknowledges that there are many definitions of SOP; however, this study only focuses on the way to improve existing questionnaires. Therefore a discussion of definitions of SOP will not be presented here. In this study, "SOP" is treated as "the subjective feeling of existence within a given environment" (Heeter, 1992, Sheridan, 1992, Slater, Usoh, and Steed, 1994, Steuer 1992)

1.6.2. Use of Presence Questionnaire (PQ) and Slater's Questionnaire (SQ) in this study only

The author of this study also acknowledges that there are many different questionnaires used to study sense-of-presence (SOP). Only Presence Questionnaire (PQ) and Slater's Questionnaire (SQ) were used in this study. This is because PQ has a high reliability (Cronbach's alpha = 0.88) and SQ is one of the most popular in use today. The latter contained 6 questions from Slater's previous research on SOP (Slater et al., 1992, 1993a, 1994, 1995, 1998, 2000 and Usoh, 2000). These questions have been used in many virtual reality related studies and induced reasonable responses. A more detailed introduction to the Presence Questionnaire (PQ) and Slater's Questionnaire are listed in Chapter 2.

1.6.3. Regression model

As this study only focuses on generating questionnaires and exploring the relationships among level of SOP, sickness, excitement and performance, a regression model of factors affecting SOP will not be constructed in this study.

CHAPTER 2

BACKGROUND LITERATURE ON QUESTIONNAIRES USED FOR MEASURING SUBJECTIVE SENSE-OF-PRESENCE (SOP)

2.1. Introduction to the Presence Questionnaire (PQ)

The Presence Questionnaire (PQ) (Singer and Witmer, 1996) is a set of questionnaires developed to measure the subjective sense-of-presence (SOP) in the virtual environment. The whole questionnaire yielded the reliability (Cronbach's alpha) of 0.88. All ratings were given in a Likert scale 7-point rating format with middle-point provided.

Dr Singer and Dr. Witmer developed the question items for PQ which were derived from the factors which are believed to have an effect on presence. These factors were control factors, sensory factors, distraction factors and realism factors. Control factors refer to the degree to which participants have control over the interactions within the virtual environments (VE). Sensory factors include the sensory modality, environmental richness, multimodal presentation, consistency of multimodal information, degree of movement perception and active search. Distraction factors consist of isolation (device which can isolate the participants from the real physical world), selective

attention and interface awareness. Realism factors are about the scene realism, consistency of information with the objective world, meaningfulness of experience and separation anxiety or disorientation. From these 4 main factors, 32 questions were generated. Dr Singer and Dr Witmer used cluster analysis method to extract 19 questions from these 32 questions and categorized them into 6 indices.

The three main indices are "involved/control", "natural" and "interface quality". Involved/control measures how well the participants felt able to control events in VE; natural measures how natural the movement control is and interface quality considers whether controls interfere or distract from task performance. The other three indices are auditory, haptic and resolution which measure "the quality or fidelity of the sensory input" of the environments. The whole questionnaire contains 32 questions and after the Cronbach-alpha test only 19 out of them are counted in the Total Score. A sample of PQ can be found on Appendix 2.1.

2.2. Concerns with using the Presence Questionnaire (PQ) as a measurement tool

Slater, M. (1999) argued for the Presence Questionnaire and this study raises questions regarding the question structures of PQ. In PQ, questions are mostly related to how participants rate the interface quality in the environment. From Slater's point of view, presence is "what an individual will express in response to questions about "being there"", while immersion is the objective measurement of what any particular system does provide. Therefore there is a conceptual flaw in the Presence Questionnaire. Singer, M. and Witmer, B.G. (1999) restated their idea of presence (i.e. "the subjective experience of being in one place or environment, even when one is physically situated in another") and immersion is the "psychological state characterized by perceiving oneself to enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences" which is contrasted with Slater et al.'s definition. In addition, in order to experience SOP, immersion is necessary and also Witmer and Singer restated that the Presence Questionnaire is "intended to measure SOP" as the questions from the questionnaire were derived from the factors which were believed to influence presence. There was also doubt as to whether PQ results are reliable. Schuemie, et al. (2001) mentioned that

PQ measured the causes of presence but not presence itself. The author of this study acknowledges there were arguments against PQ and therefore Slater et al.'s proposed questions (Slater's Questionnaire) on measuring presence were also adapted to access the level of SOP that participants experienced.

In addition, there were comments regarding the moment at which to present the PQ to the participants. There was a delay between the experience of presence and participants' report of presence allowing the participants to forget some aspects of their experience, and removing the participants from the environment to fill in the questionnaire would also have an effect on the measurements (Snow and Williges, 1996). However the Vien and Olsson study (2001) shows that there were no significant differences caused by filling the Presence Questionnaire inside or outside the experimental environment. Therefore in this study, the questionnaire was still presented to the participants after the participants left the experimental environments.

Even though there were many studies raising doubts on Presence Questionnaire, Presence Questionnaire was one of the larger and more complete questionnaire to measure SOP (Nash, et al.,2000). This questionnaire also shows a high internal consistency (alpha = 0.88) (Witmer

and Singer, 1996) and also comprehensive to statistical analysis (Nichols, et. Al, 2000).

2.3. Introduction to Slater's Questionnaire

Slater's Questionnaire was a combination of questions from Slater's previous studies on SOP (Slater et al., 1992,1993a, 1994, 1995, 1998,2000 and Usoh, 2000). The whole questionnaire consists of 6 questions in Likert Scale 7-point rating and 2 open questions which let the participants fill in what they think would increase and "pull" them out of the feeling of "being in the environment". These questions were generated based on Slater and his colleagues' ideas on presence:

(1) the subjective sense of being there

(2) the extent to which the virtual environment becomes the dominant - the participants tend to be more responsive to the events happening in the virtual environment rather than in the real environment

(3) after experiencing the virtual environment, participants will remember it as a place rather than just images

The two open questions were considered as the best way to explore the subjective SOP that participants experienced: therefore these questions were

also adapted. Samples of Slater's Questionnaire can be found in Appendix 2.1.2.

2.4. Concerns with using Slater's Questionnaire

Slater's questionnaire also received attention in presence research. As this questionnaire not only concern the subjective sense rating of SOP, it also explores how participants responses to the idea of sense of being via open questions. Unlike PQ which attempts to measure presence by measuring its causes rather than the results of presence, Slater's questionnaire is strictly related to the results of presence (Schumie, 2001). However there was inconsistency of Slater's Questionnaire measurements (Snow, 1996) and this caused some drawbacks on using the Slater's Questionnaire as a measurement tool.

CHAPTER 3

LITERATURE ON SENSE-OF-PRESENCE (SOP) AND TASK PERFORMANCE

3.1 Environments affect sense-of-presence (SOP)

In this section, studies related to how the system or environment displays on affecting sense-of-presence (SOP) was reviewed. The system displays included visual, audio, smell, taste and sense of touch and they are called as sensory interface variables in this study. When the sensory interface of the environments changes, it affects the overall experience of the participants towards the environments and hence the SOP felt by the participants also changes.

Many studies have shown that degrading the sensory interface of the virtual environments (VE) can result in a lower subjective SOP in users. The investigated sensory interface variables include field-of-view (FOV), display resolution, viewing mode, sense of touch and also image delay. For example, Hendrix and Barfield (1996) and Snow and Williges (1998) show that wider the field-of-view (FOV) induce higher level of SOP to the participants. In the Hendrix and Barfield (1996), participants experienced significantly higher level of SOP with 50^0 and 90^0 Geometric FOV in a virtual simulation when compared with using 10^0 GFOV ($p<0.05$). In the Snow and Wiliges study, there was significant effect of field-of-view (48 x36, 36 x 27, 24 x 18 in deg.) on SOP was found ($p<0.05$). Freeman, et al (1999) and Barfield and Hendrix (1996) studied effects of stereoscopic and monoscopic on level of SOP and they both showed that VE with stereoscopic view led to a

significantly higher subjective level of SOP from the participants than the participants viewing with monoscopic view ($p<0.05$). However on the effect of resolution, there were 2 different opinions. In the Dinh et al. (1999) showed that visual detail was not a significant factor to the participants' subjective level of SOP ($p>0.05$). In their study, the set up of the visual detail level was by mapping different resolution texture on the objects. The higher resolution texture represented higher visual detail level and vice versa. However there were no significant differences between higher and lower mappings virtual stimulation in terms of the level of SOP that participants experienced ($p>0.05$), in other words, the visual detail had no significant effect on the participants' SOP. However, Snow and Williges (1998) showed that visual display resolution (320 x 200 Vs 640 x 480) was a significant factor towards the way the participants experienced SOP ($p<0.05$) and the higher the resolution, the higher the level of SOP that participants experienced. On the effect of image delay on SOP, Welch et al. (1996), Barfield et al. (1995), Welch et al. (1996) and Snow and Williges (1998) showed that image delay has a significant effect on the level of SOP that participants experienced ($p<0.05$). Welch and his colleagues found that participants exposed to a (350 – 370) ms image delay virtual environment had a significantly lower SOP that participants exposed to a (200-220ms) image delay ($p<0.05$). Barfield and his colleagues studied the effects of image delay by using the update rate, and there were four levels of update rate they used which were 5, 10, 15, 20, 25 Hz. Their result showed that at least a 15 Hz refresh rate of the scene could make the users feel present in VE. Snow and Williges also found that there was a significant effect of image

delay on participants' SOP by using 3 levels of update rate which were 8, 12 and 16 Hz.

Above studies hinted that participants in any environment in which the sensory interface was lower than the real environment would experience a SOP lower than that of the real environment. And also the highest SOP should appear in a real environment or any environment which has the same level of sensory interface as the real environment in which we live daily.

Other than the sensory interface variables, task was also believed to be another component affecting the participants' experienced SOP, such as task difficulty (Sheridan, 1992). As the task complexity and difficulty was controlled throughout this study, the task factor will not be explored. The tasks carried out by the participants in this study are taken from the Virtual Environment Performance Assessment Battery (VEPAB) developed by Lampton and his colleagues in 1994. Appendix 3.1 contains a description of VEPAB.

Several effects of sensory variables on SOP have been discussed in the earlier part of this section, such as effects of FOV, visual resolution, stereoscopic vs monoscopic views and image delay. Why do we still want to study these sensory variables? The answer is that so far there has been no single experiment which can investigate all of these sensory variables (field-of-view, visual resolution, stereoscopic vs. monoscopic and image delay) together. Furthermore, there was no single experiment could include the large range of sensory variables from virtual to real environments. By doing this extensive study, a more completed understanding on effects of sensory variables on SOP could be found.

3.2 Individual effects of sensory related variables on the task performance

Display's field-of-view (FOV): Well and Venturino (1989) studied the effects of display's FOV on task performance in a virtual environment. A binocular head-mounted display was used and the FOV varied from 20x20 to 120x60 (azimuth degrees x elevation degrees). Ten participants performed a series of search and acquire tasks in which they had to memorize the spatial locations of some targets and recall them in the absence of target cue (primary tasks). These tasks were presented in a flight simulation environment and the participants had to maintain the flight level as their secondary tasks. Results suggested that although visual search performance can be maintained with small FOVs, it is done in a manner which may compromise performance with other concurrent tasks. In a study concerning object size estimation, Henry and Furness (1993) reported that users in a virtual environment underestimated the size of viewed objects. The suggested explanation was that the limited FOV of the head-mounted display and the edges of the display made the objects appeared systematically smaller.

Image resolution: In 1995, Smets and Overbeeke investigated the effects of image resolution on a 3 dimensional jigsaw puzzle task. The task was presented in a 'real' environment and participants viewed the task through the captured images by a head-mounted monoscopic camera. A head-mounted display was used to present the captured images and the image resolutions studied were: PAL 625 lines video, Mosaic 36x30, and Mosaic 18x15. Results indicated that the task completion time increased significantly with decreasing resolutions.

Stereoscopic presentation: Arthur et al., (1997) compared the perception of spatial layout of three dimensional objects viewed in a 'real' (stereoscopic) and 'virtual' (monoscopic biocular) environment. Participants were allowed to change their views using head movements within both environments. After viewing the objects, they were then asked to recall the locations of the objects in their absence. No significant difference was found between the two conditions. This suggested that biocular 'virtual' environment with head tracking could be used to present spatial information. A similar finding was reported by Lane and Akin (1997). They reported that although both stereopsis and head tracking increased the perception of depth in a virtual environment, head tracking seemed to dominate the stereopsis advantage.

Image lags related to head movement: So and Griffin (1992, 1995, and 1996) studied the effects of image update lags on continuous head tracking performance within a virtual reality system. Significant degradation in performance was found with imposed lags of 40 ms or more. Practices did not reduce the effects of lags and lag compensation by head position prediction and image deflection had shown to be effective. In 1997, Rogers et al. reported a study of the effects of lags on target acquisition task using discrete head movement. Results showed that target acquisition time increased linearly with increasing lags and the increases were significant for lags greater than 20 ms. Ellis et al.. (1997) reported a study of the effects of lags on hand tracking performance in a virtual environment. Results indicated that a system latency of less than 50 ms is required if a tracking precision of 1.8 cm or less is needed.

Image qualities: Studies of image qualities on task performance in a virtual

environment have not been studied. Pasman et al. (1997) reported a related study on tele-operation. Results indicated that the performance of a three dimensional shape detection task improved with increasing number of grey levels. Subjects were asked to detect certain objects from viewing their black-and-white x-ray images. Interacts were found between the image resolution and the number of grey levels used.

Auditory interface: The importance of auditory stimuli in a virtual environment has long been recognized (Sutherland, 1965). With the development of spatial sound technologies using head-related transfer functions (e.g. Blauert, 1983), three-dimensional sound presentation has become a reality. In 1993, Cohen presented the use of two audio windowing systems in manipulating the harmonics, intensity, timing, and spatial information of sound presentations.

Sense of touch interfaces: Although the benefits of tactile and force feedback in a virtual environment have generally been recognized (Barfield et al., 1995), research effort in this area is hampered by the cost of equipment. Researchers in Japan experimented with a parallel rod system to simulate tactile feeling and forces at different surface interfaces (Koichi and Michitaka, 1995). Results indicated that the device could simulate the feeling of a curved surface, although the shapes detected by the subjects were different from the intended shapes. This system used 16 parallel rods powered by servomotors.

3.3 Sense-of-presence (SOP) and levels of excitement

Some studies show that SOP was closely associated with the level of excitement that participants felt. Slater's study (1999) suggested that a participant's individual enjoyment and satisfaction can contribute to presence and hence different participants in the same environment can have different levels of presence. There was also a positive relationship found between presence and level of enjoyment (Nichols et, al., 2000). Although the field of participants' enjoyment is less focused on in this study, from previous studies it seems that the participants' enjoyment can add some value to presence.

Currently, there is not yet a standard questionnaire in measuring the levels of excitementt in the VR simulation. In the third experiment, an excitement questionnaire was developed and used. Also, an innovative and novel method to test the 3D perception of participants of the environment that they were exposed to was developed and tested. The method is referred to as "perspective drawing".

3.4 Sense-of-presence (SOP) and cybersickness

Witmer and Singer (1996) found that there was a significant negative correlation between SOP and sickness ($p<0.05$). The same finding was also shown in Nichols et al.'s, (2000) on association between presence and sickness. In the third experiment, the levels of sickness was measured by the Simulation Sickness Questionnaire (SSQ). Appendix 3.2 contains a description of the SSQ and a sample SSQ that was used in this study.

CHAPTER 4

INTRODUCTION TO EXPERIMENTS

4.1. Overview of the three experiments

There were 3 experiments conducted in this study. The logical flow of these experiments in this study was shown in Figure 4-1 and their purposes were mentioned in this chapter.

4.1.1. Experiment 1- determine the ability of the Presence Questionnaire (PQ) to differentiate the reported sense-of-presence (SOP) from participants in a virtual environment (VE) and its corresponding real environment (RE).

Usoh et al (2000) reported that the Presence Questionnaire (PQ) failed to report a significant difference between the sense-of-presence (SOP) associated with a virtual environment (VE) and its corresponding real environment (RE). Since the PQ was developed to measure SOP in a VE, the failure should have been caused by the failure of PQ in measuring SOP in a RE. This experiment (Experiment 1) was to verify whether the existing PQ can different the level of SOP that the participants experienced from real to virtual environments. In addition, the complications that occurred by using the PQ to measure the levels of presence when participants immersed in a real environment would be identified. The results of Experiment 1 were documented in Chapter 5.

4.1.2. The use of Cooper-Harper Technique to present the Presence Questionnaire (PQ)

The Cooper-Harper Technique (Cooper and Harper, 1969) was adapted to solve the problems identified from Experiment 1. There were 2 problems identified and they were related to PQ question style, one was associated with the misunderstanding of the questionnaire due to terms and another problem was the participants in RE reluctant to choose extreme position ratings in the questions where extreme position ratings should be occurred. The extreme position ratings in this study mean the rating-1 and rating-7. The result of the participants avoiding the extreme position ratings was that the central tendency distribution on the PQ question scoring occurred. When using the Cooper-Harper technique, the PQ questions could be explained in more details and also encourage participants to choose the extreme position ratings on the questions that extreme position ratings should be occurred. Details on presenting PQ in Cooper-Harper rating are documented in Chapter 6. The PQ that presented in the Cooper-Harper technique was called Cooper-Harper rating Presence Questionnaire (CHRPQ) and listed in Appendix 2.1c.

4.1.3. Experiment 2- Validate the usability of the Presence Questionnaire presented in Cooper-Harper style (Cooper-Harper rating Presence Questionnaire, CHRPQ)

Experiment 1 reported that in 18 out of the 32 questions in PQ, participants had been conservative in selecting rating 1 or 7 even though these ratings were deemed to be appropriate through logical deduction. In this experiment (Experiment 2), the benefits of using Cooper-Harper technique to present the PQ was studied. It was hypothesized that Cooper-Harper presentation style can minimize the inappropriate avoidance of rating –1 and 7 in those 18 questions. The results can be found in Chapter 7.

4.1.4. Experiment 3- studying the relationships among SOP, cybersickness, performance, and levels of excitement in Virtual Environments, Telematic Environment, and Real Environments showing similar visual and audio content.

As mentioned in Section 3.1, the main effects of field-of-view, stereoscopic view, display resolution, image delay, auditory and the availability of sense of touch on sense-of-presence (SOP), performance, and cybersickness have not been studied in a single experiment. In Experiment 3, these 6 sensory variables were manipulated to construct experimental environments ranging from Virtual Environments to Telematic Environment to Real Environments and

the effects of these 6 sensory variables on SOP, performance and cybersickness were studied in this experiment. In order to optimize the effects, the orthogonal array (OA) design was used. In addition, the relationships among SOP, cybersickness, performance and levels of excitement were also under investigation. The results were documented in Chapter 8.

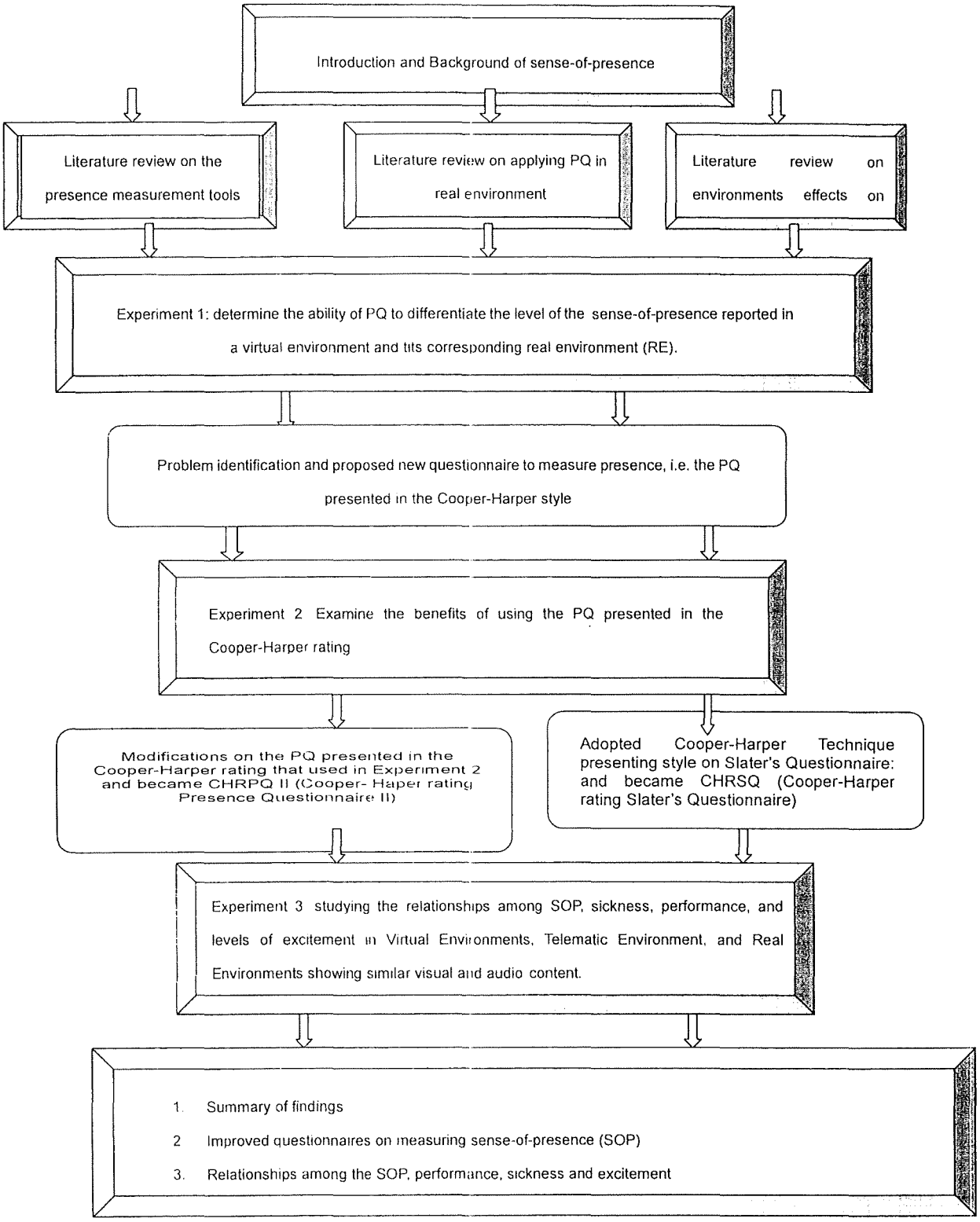

Figure 4-1: Flowchart of this study

4.2. Dependent variables in the three experiments

The goal of this study associated with sense-of-presence (SOP), performance, cybersickness, and levels of excitement. The dependent variables of this study were to satisfy this goal and they were described as below.

4.2.1. Dependent variables in Experiment 1

There were 4 dependent variables in this experiment which were (1) individual tendency of immersive (ITI) levels and (2) subjective level of SOP that the participants experienced, (3) moving cylinder task completion time and (4) visual search completion time. In the following sections, each dependent variable was described in details.

4.2.1.1. Individual tendency of immersive (ITI) level:

Individual tendency of immersive (ITI) level was measured by adapting the Immersive Tendency Questionnaire (ITQ) (Singer and Witmer, 1996) and its Total Score reflected the individual tendency of immersion. The ITQ was developed to " identify real world behaviors and tendencies that may predict how much presence individuals will or can experience presence in a remote or artificial environment." Its reliability is 0.81 that is in the reasonable level

(Witmer and Singer, 1996). Totally there are 34 questions (all in a 7-point Likert scale) and 19 of them are counted to the Total Score. The higher the Total Score means that the higher the tendency of the participant is able to immerse to the environment. In order to let the participants understand the questions easily, some Chinese translations and examples were also added in blankets in the ITQ. The meaning of the original questions were not changed and so as the words. A sample ITQ used in the experiments is included as Appendix 4.1.

4.2.1.2. Subjective level of sense-of-presence (SOP)

Subjective level of sense-of-presence (SOP) that participants experienced in Experiment 1 was measured by using the Presence Questionnaire (PQ) (Witmer and Singer, 1996; see Section 2.1) and according to its instructions to calculate the Total Score which was the indicater of the levels of SOP that the participants experienced. A higher the Total Score means a higher the SOP that the participants experienced. The six PQ subscores, involved/control, natural, interface quality, auditory, haptic and resolution, were also calculated. A sample of the PQ can be found in Appendix 2.1a.

4.2.1.3. Moving cylinder task completion time

The moving cylinder task required the participant to grasp the purple cylinder from his/her RHS (point A) and put it on his/her LHS (point B) and then take it back to the point A within the assigned environment. The horizontal distance between point A and point B is about 72 cm. For 1 trial, above actions were repeated 5 times. After the 5th time. he/she put the cylinder back on the point A and put his/her right hand on the green button and that was the completion of 1 trial in the moving cylinder task. The moving cylinder task completion time was the total time required for the subject to finish 5 moving cylinder trials.

4.2.1.4. Visual search completion time

In the visual search task, a participant sat in the seat and a table placed in front of him in the assigned environment. During the visual search task, the participant would read out the instructions on the table and find out what exactly he needed to search in this task. When the participant found out what he needed to search, he would turn around his head to find certain objects on the walls surrounding him and without leaving the sear. Once the participant identified and found the object that he was asked to find, he needed to utter the answer immediately. The visual search completion time was measured from the time when the participant started searching what s/he needed to find to the time when s/he uttered out the answer.

4.2.2. Dependent variables in Experiment 2

All of the dependent variables were similar to Experiment 1 except on SOP. In this experiment, the SOP was measured by using the Presence Questionnaire presented in Cooper-Harper style (CHRPQ, see Appendix 2.1c) scores. Detailed descriptions of the other measurements such as ITI level, moving cylinder task completion time and visual search completion time can be found in the section 4.2.1.

4.2.3. Dependent variables in Experiment 3

Similar to Experiment 1 and 2, the (i) ITQ scores, (ii) the PQ scores and subscores, (iii) the moving cylinder task completion time, and (iv) visual search completion time are the dependent variables. Furthermore, there were (1) the Cooper-Harper rating Slater's Questionnaire scores, (2) cybersickness level and (3) perspective drawing on measuring SOP. Descriptions of the new dependent variables were listed below.

4.2.3.1. The Slater's Questionnaire presented in Cooper-Harper style(Cooper-Harper rating Slater's Questionnaire, CHRSQ) scores

Although there was PQ score already, another way to explore SOP in this experiment to provide a better view on SOP was the Slater's Questionnaire presented in Cooper-Harper rating, Cooper-Harper rating Slater's Questionnaire (CHRSQ, Appendix 2.2c). The CHRSQ was the Slater's Questionnaire presented in Cooper-Harper style and details of the Slater's Questionnaire can be found in Appendix 2.2.

4.2.3.2. Cybersickness level

Simulator Sickness Questionnaire (SSQ) (Kennedy, et al, 1993) was adapted to measure the induced cybersickness level. SSQ contains 29 symptoms investigating simulator sickness with a 4-point rating scale: none, slight, moderate and severe. The whole SSQ actually contains of 2 set of questionnaires and both of them list out the same symptoms. One set of SSQ was used before exposed to the environment which is called Pre-SSQ and another set was used after exposed to the environment which is called Post-SSQ. The symptoms are divided into 3 clusters, and a Total Score which reflect the overall level of cybersickness that the participants experienced. The

3 clusters are Nausea, Oculomotor and Disorientation. These 3 clusters levels were expressed in scores and their calculation methods were listed in Appendix 3.2.

4.2.3.3. Participants' excitement level

The individual participant's excitement level was measured by Excitement Questionnaire (Appendix 4.2) and expressed in scores. The Excitement Questionnaire is a set of questionnaire which was built to measure the level of participants' enjoyment towards the overall experience, towards the tasks and towards the environments respectively. Each question was presented in Likert scale 7-point rating and participants were told to avoid taking the middle-point. The reason of introducing excitement levels was because there was past study (Nichols et al., 2000) showed enjoyment added value to SOP. In addition, this can be an important contribution towards the computer game industry. For example, if excitement is positively related to SOP, in order to improve the excitement levels of the game users experienced, we can achieve this by increasing the level of SOP instead.

4.3. Apparatus

This section described the apparatus used for setting up the experimental environments in each experiment.

4.3.1. Apparatus used in Experiment 1

The experimental environments were (i) a virtual environment (VE), (ii) a telematic environment (TE), (iii) a real environment viewed through a headset of restricted field-of-view (RE_restricted), and (iv) a real environment with a head-mounted weight but no restricted field-of-view (RE_weight).

In each experimental environment, a Polhemus 3SPACE® tracking system (Kaiser Aerospace and Electronics Company, Colchester, USA) was used to track the positions and orientations of the participants' heads and their right hands. CyberGlove™ (Immersion Corporation, Palo Alto, USA) to measure the hand gestures of participants in the VE. In both the VE and TE, participants viewed the environments via a VR4 head-mounted display (see Figure 3d) (Virtual Research Systems, Santa Clara, USA). In the VE, the scene presented on the HMD was generated by a Silicon Graphics Onyx2 Infinite Reality workstation (Silicon Graphics, Inc., USA). In the TE (see Figure 3c), scenes

presented on the HMD were video pictures of a real environment captured by a PC 90 computer via a head-mounted camera (Panasonic colour camera GP-KR521, Yokohama, Japan). A special headset of the same weight as the VR4 HMD was used in both the RE_restricted and RE_weight (see Figure 3a and 3b). The participants in the RE_weight, RE_restricted and TE wore a softball glove to simulate the CyberGlove™ used in the VE.

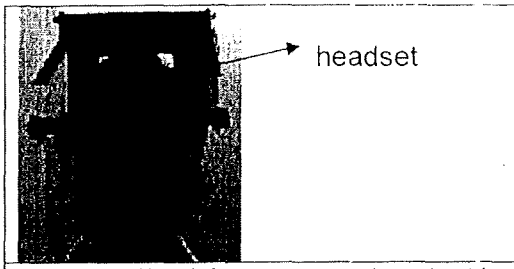

Fig 4-2a. Participant wore a headset in RE_weight

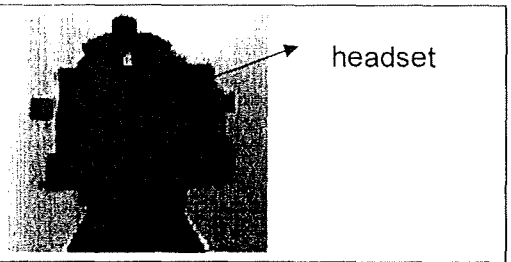

Fig 4-2b. Participant wore a headset in RE_restricted

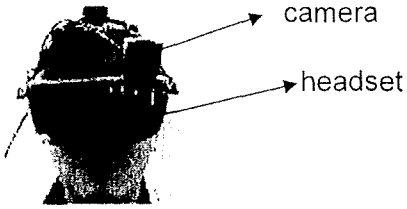

Fig 4-2c. Participant wore a camera with headset in TE

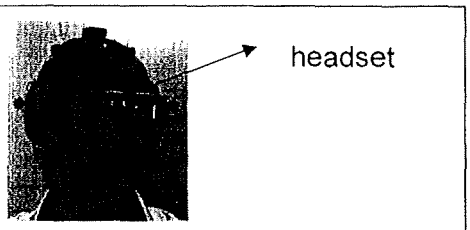

Fig 4-2d. Participant wore a headset in VE

Figure 4-2 Experimental apparatus on participant's head in each experimental environment: RE_weight, RE_restricted, TE and VE

4.3.2. Apparatus used in Experiment 2

In Experiment 2, four experimental environments were built with same contents shown , 3 out of the four experimental environments are same as in Experiment 3 which are the (i) a virtual environment (VE), (ii) a telematic environment (TE), (iii) a real environment with a head-mounted weight. The fourth experimental environment is the Real Environment (RE). RE is the environment that the participants were placed in a real room without wearing any HMD or headset or glove. Also the participants were not attached with any tracker cables, i.e. RE is a cable free environment just same as our daily life real world.

4.3.3. Apparatus used in Experiment 3

In Experiment 3, there were 12 experimental environments built with same contents shown. 9 out of 12 were virtual environments and the other 3 were (x1) a telematic environment (TE), (x2) a real environment viewed through a headset of restricted field-of-view (RE_restricted) and (x3) a real environment (RE). (x1) the telematic environment was the environment where all scene were captured by 2 USB cameras (Panasonic PC Color Camera

GP-KR651US, Yokohama Japan) through the 2 PII400 computers and sent back to a V8 head-mount-display (HMD) (Virtual Research Systems, Santa Clara, USA). The participants in the TE viewed the environment by using the V8 HMD. Participants in TE were also required to wear the softball glove with a tracker mounted on the wrist area. Apparatus used in RE_restricted (x2) and RE (x3) were same as in Experiment 3. Other than RE (x4), a Polhemus 3SPACE® tracking system (Kaiser Aerospace and Electronics Company, Colchester, USA) was used in all of the other experimental environments to track the positions and orientations of the participants' heads and their right hands. For the sound effect, TEAC PowerMax 80/2 stereo speaker systems were used.

For the virtual environments:

CyberGlove™ (Immersion Corporation, Palo Alto, USA) was used to measure the hand gestures of participants in the VE. Participants viewed the environments via a VR4 or V8 head-mounted display (Virtual Research Systems, Santa Clara, USA) depended on the environment. In the VE, the scene presented on the HMD was generated by a Silicon Graphics Onyx2 Infinite Reality workstation (Silicon Graphics, Inc., USA). The sound effect that the participants heard from the environments were played through the

headphones (Philips SBC HE900/00, China) which were connected to The Aureal 3D™ sound server (Acoustetron II™, Crystal River Engineering, Inc ., Fremont, CA). Verbal instructions and real stereo effect, sound were played through the TEAC PowerMax 80/2 stereo speaker systems were used.

4.4. Experiment Tasks

All the tasks carried out by the participants were adapted from Virtual Environment Performance Assessment Battery (VEPAB). The Virtual Environment Performance Assessment Battery (VEPAB) (Lampton, *et al.*, 1994) is "a set of tasks developed to support research on training applications of virtual environment technology". These tasks divided into 3 categories: vision, locomotion, tracking and object manipulation tasks which involved the participants interacting positively with the experimental environments. Vision tasks included visual acuity test, color blindness test, visual search on static and dynamic objects and object size estimations. Locomotion tasks required participants to walk and fly around the environments actively. Tracking tasks required participants to track static and moving objects by using head and some control devices. Object manipulation was to assess the ability of participants on grasping, rotating, sliding and dragging objects. For each task,

completion time and accuracy can be measured and as dependent variables for experimenters to assess the performance. Detailed description of VEPAB can be found in Appendix 3.1. The criteria of task selections were (1) should be able to implement in all the experimental environments in each experiment and (2) the tasks performed in all the experimental environments in each experiment should be the same that allowed comparison of data among the experimental environments. Due to the criteria (1), the visual search on dynamic objects and tracking task were not implemented. Other than the VEPAB tasks, sound localisation task was also implemented, as it was quite a common event in the real world. The printed task instructions were given to the participants before entering the experimental environments, these instructions were listed in Appendix 5,7,8.

CHAPTER 5

Experiment 1: Determine The Ability of The Presence Questionnaire (PQ) To Differentiate The Reported Sense-Of-Presence (SOP) From Participants In A Virtual Environment (VE) And Its Corresponding Real Environment

5.1. Introduction

As the technology is improving rapidly, it is not hard to imagine that our virtual environments can be as good as real environment within the near future. However how about our tools which used for measuring the level of sense-of-presence (SOP) which the participants experienced? Can the current presence questionnaires such as the Presence Questionnaire (PQ, Singer and Witmer, 1996), which usually used for measuring level of SOP that participants experienced in virtual environments, also able to measure SOP experienced in real environments? This question would be answered in this experiment, Experiment 1.

5.2. Objectives

The aim of this experiment is to study whether the Presence Questionnaire (PQ) developed by Singer and Witmer (1996) can differentiate the level of sense-of-presence (SOP) between the virtual and real environments.

5.3. The environments, variables, and design of experiment

There were four environments ranging from virtual to real were constructed for this experiment which were (i) virtual environment (VE), (ii) telematic environment (TE), (iii) real environment with restricted field-of-view (RE_restricted), and (iv) real environment with non-restricted field-of-view but with head-mounted weight (RE_weight). Table 5-1 shows 4 pictures each illustrates a participant wearing the appropriate head-mounted apparatus in each of the four environments. Table 5-2 illustrates the differences in the level of field-of-view, image quality, display resolution, imposed time delay, auditory, the availability of tactile feedback and head-mounted weight.

All 4 environments show the similar visual and audio content which consists of a rectangular room, a table with various objects on top, a curtain, a wall-mounted clock, carpeted floor, and ceiling with lights. This rectangular room is an acoustic room, therefore participants would not be disturbed by the noises outside the experimental environments during the experiment. Figure

5-1 illustrates perspective drawings of the visual content of the 4 environments surrounding the participants (all 4 environments show the similar visual content). Figure 5-2 illustrates a sample view from a participant in each of the 4 environments.

These 4 environments represent the 4 levels of the only independent variable in this study- the experimental environment. A full-factorial between subject experimental design was used. There were 4 conditions and 48 participants were randomly assigned into groups of 12 for taking part in one condition. All of these 48 participants were Hong Kong Chinese male volunteer participants ages ranged from 19 to 25. They were all right-handed, had normal or corrected to normal eyesight, and did not have colour-blindness. The use of male participants only in this experiment was because the recruitment was done on engineering school which had a comparatively high population of male.

Table 5-1 Illustration of a participant wearing the appropriate head-mounted apparatus in each of the four environments

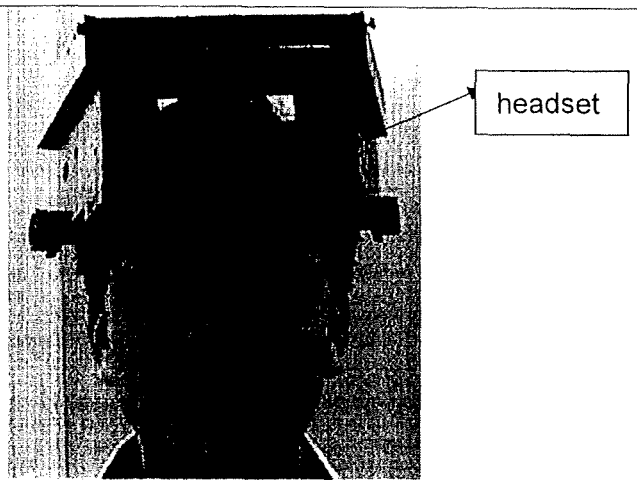

Table 5-1a This figure illustrates a participant who was wearing a special made headset on his top of his head in the RE_weight environment.

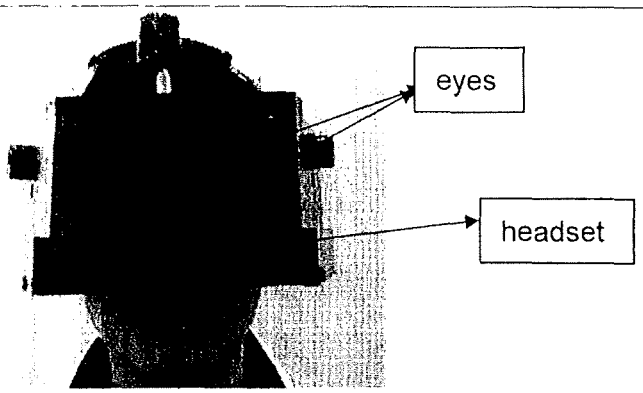

Table 5-1b This figure illustrates a participant who was wearing a specially made headset on his top of his head in the RE_restricted environment. While the participants were wearing this headset, their field-of-view were restricted from 140 deg x 90 deg (normal field-of-view) to 48 deg x 36 deg (restricted field-of-view)

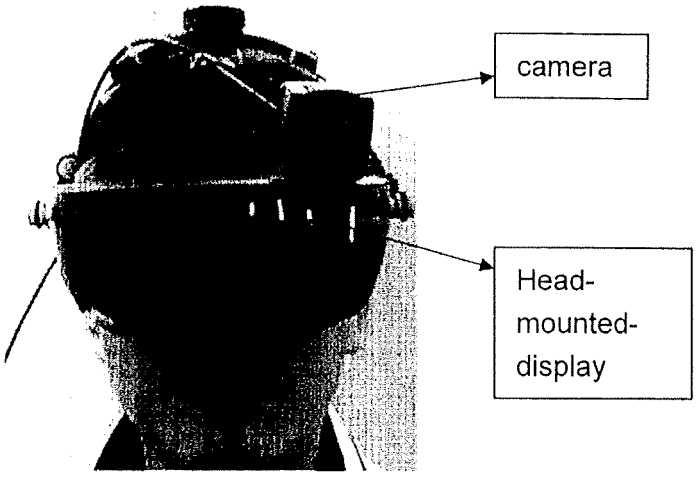

Table 5-1c This figure illustrates a participant who was wearing a head-mounted display with a camera on the top of it. The participant would see the scene through the head-mounted display captured by the camera on the top. The participant would view the scene in biocular mode as his both eyes were viewing the same image.

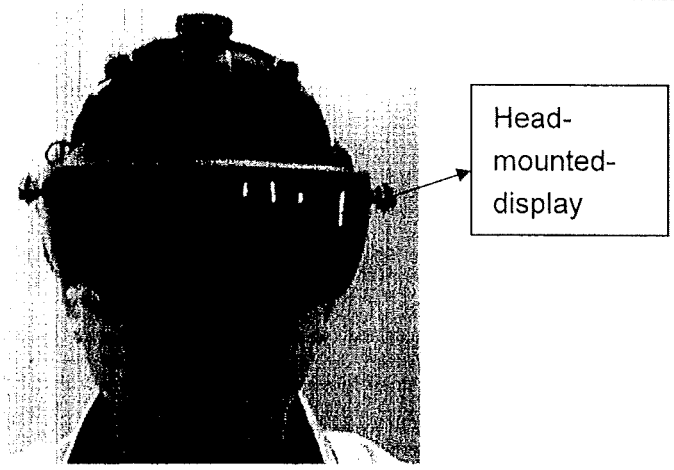

Table 5-1d This figure illustrates a participant who was wearing a head-mounted display in a VE environment. In this environment, the participant could only view the environment via the head-mounted display and all the scenic view that he saw were computer graphics.

Table 5-2 Illustration the differences in the levels of field-of-view (FOV), the availability of stereoscopic view, imposed time delay, resolution, auditory , the availability of tactile feedback, and head-mounted/headset weight

	The four experimental environments			
Sensory Interface variables	*RE_weight*	*RE_restricted*	*TE*	*VE*
Field of view (horiz. x vert.) in deg	140^0x90^0	48°x36°	45°x34°	48°x36°
Biocular/binocular view	binocular	binocular	biocular	biocular
Imposed Image Lag	without	without	approx. 130ms	approx. 60 ms
Image Quality	real	real	camera	computer-generated
Display Resolution in pixels (horiz. X vert.)	8400 x 5400	8400 x 5400	475 x 115	475 x 115
Auditory	real & spatial	real & spatial	real & spatial	real & spatial
Tactile	with	with	with	without
Headset/head-mounted display weight	1kg	1kg	1kg	1kg

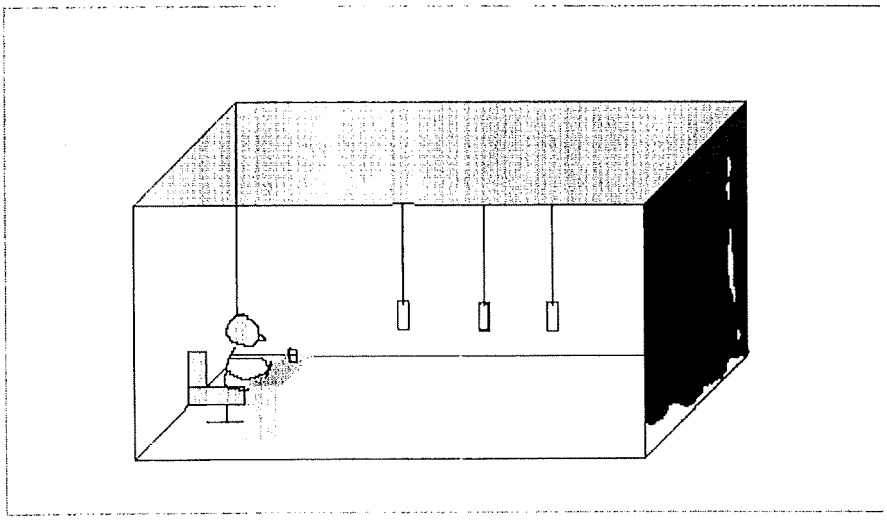

Figure 5-1a A 3D perspective of the experimental environment

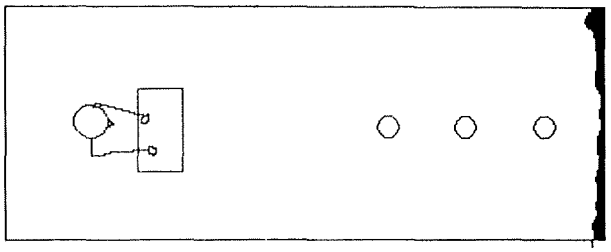

Figure 5-1b A view from the top of the experimental environment

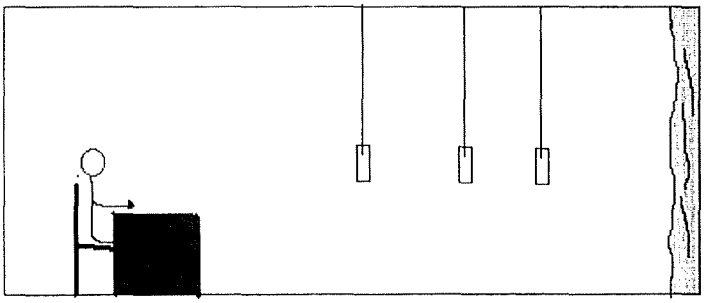

Figure 5-1c A side view of the experimental environment

Figure 5-1 illustrates perspective drawings of the visual content of the 4 environments surrounding the participants (all 4 environments show the similar visual content).

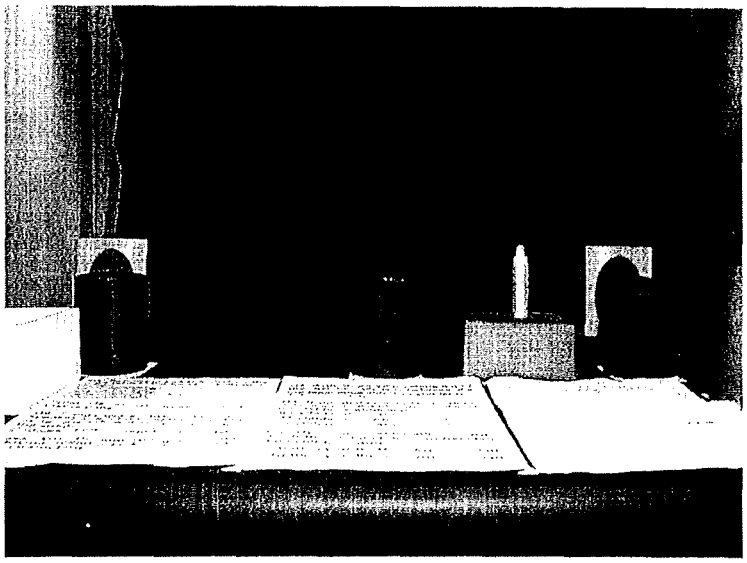

Figure 5-2a A sample view from a participant in the real environments which were the real environment without the restricted field-of-view but with headset weight (RE_weight) and real environment with restricted field-of-view (RE_restricted)

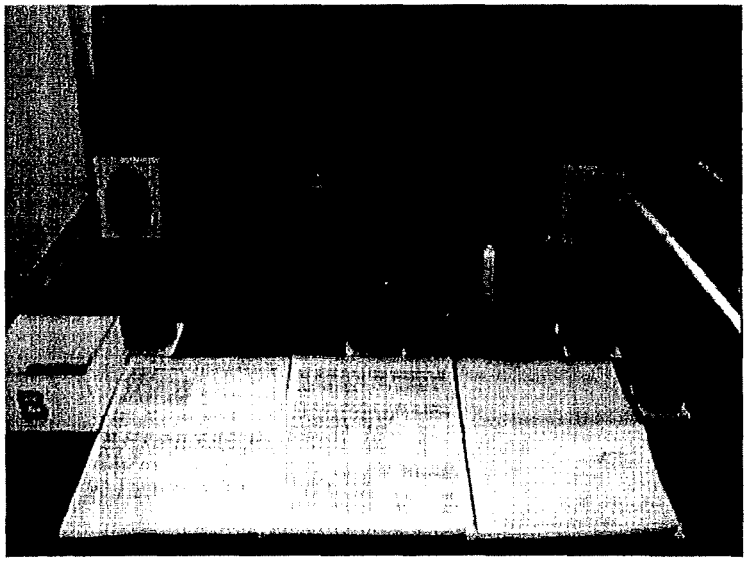

Figure 5-2b A sample view from a participant in the telematic environment (TE) which were the RE_weight and RE_restricted

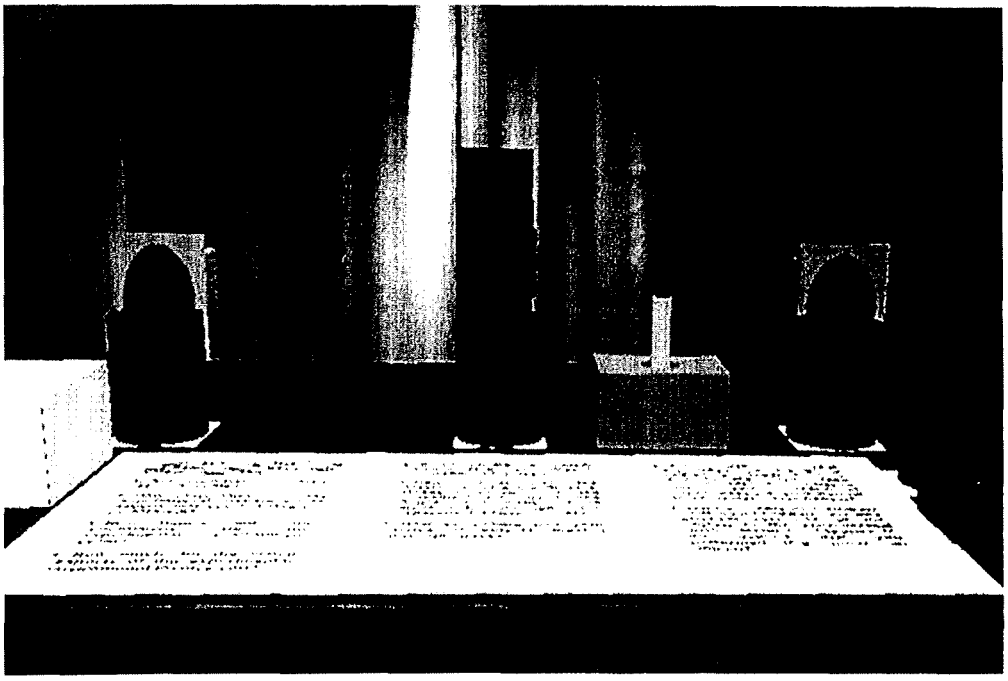

Figure 5-2c A sample view from a participant in the virtual environment

Figure 5-2 illustrates a sample view from a participant in each of the 4 environments.

The dependent variables of this experiment consists of (i) the level of tendency of immersion, (ii) the PQ scores and subscores, (iii) the completion time of moving cylinder tasks, and (iv) the completion time of visual search tasks. Details of the 4 dependent variables are already explained in Chapter 4.

5.4. Hypotheses

It was hypothesized that the Presence Questionaire (PQ) would not be able to differentiate the level of sense-of-presence (SOP) that the participants reported from the virtual environment (VE) and its corresponding real environment (RE_weight). In 2000, Usoh and his colleagues reported that the PQ failed to report a significant difference between the measured SOP in a VE and its corresponding RE while the presence questionnaire developed by Slater-Usoh-Steed (2000) reported a significant difference in their scores.

5.5. Procedure and Tasks

Participants were asked to fill in the consent form and then instructions about the task would be explained to the participants. The participants also received a hardcopy of the experiment instructions about what they were asked to do within the assigned experimental environments. Once the participants were ready, they were given the Immersive Tendency Questionnaire (ITQ) to fill in before entering the experimental environments. After this, the participants got into the experimental environments that they were assigned to and carried out the moving cylinder and visual search tasks which were mentioned in Section 4.2.1.3 and 4.2.1.4 respectively. When the participants left the experimental environments and the Presence

5.6. Results

5.6.1. Reliability of the Presence Questionnaire (PQ)

To evaluate the internal consistency of the PQ, Cronbach's alpha test was performed on the 48 sets of PQ raw score. The alpha value is 0.8576 (> 0.8), this was considered as a high internal consistency (Breakwell, 1995).

5.6.2. Effects of experimental environments on the Presence Questionnaire (PQ) subscales' scores and the PQ total scores

From the observation of the graph (Figure 5-3), the Presence Questionnaire (PQ) was able to differentiate the level of sense-of-presence (SOP) that participants experienced between real and virtual environments. One can see from the Figure 5-3, the variations of subjective SOP measured by the PQ along the four experimental environments. The level of involved/control was decreasing in the order of RE_weight, RE_restricted, TE and VE. The subscales for natural, haptic and resolution increased in the order of VE, TE, RE_weight and RE_restricted and in resolution subscale, the order was increasing in VE, TE, RE_restricted and RE_weight. For the total score which represented the level of subjective sense of presence, participants in both real environments (RE_weight and RE_restricted) were the highest and then followed by TE and VE. However, RE_restricted was slightly higher than RE_weight which was against the stated hypothesis.

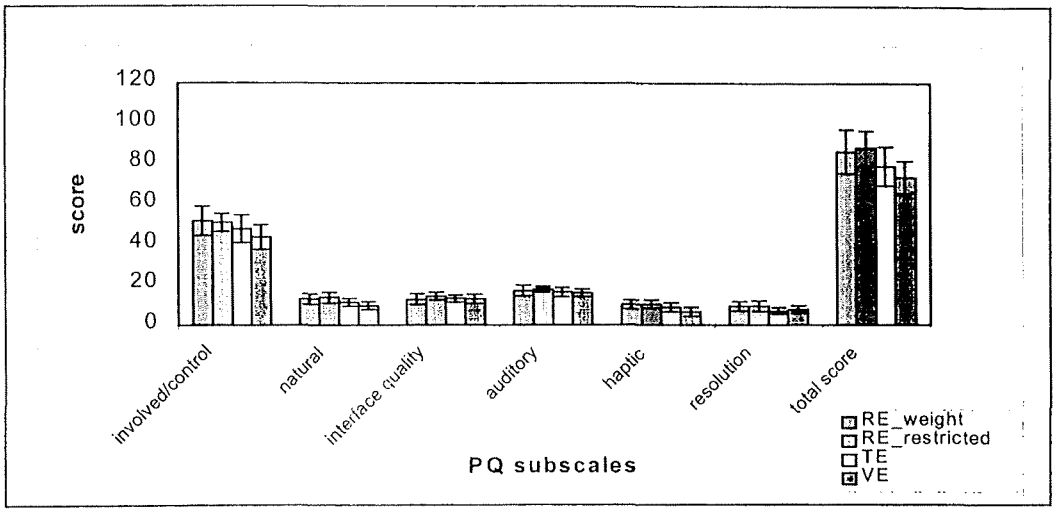

Figure 5-3 The mean and standard deviations of all Presence Questionnaire (PQ) subscales and total among the four experimental environments: a real environment with a head-mounted weight but no restricted field-of-view (RE_weight), a real environment viewed through a headset of restricted field-of-view (RE_RESTRICTED), telematic environment (TE) and virtual environment (VE).

Further statistical analysis (see Table 5-3) shows that not all of the subscales were significant differences among the experimental environments. Only the Involvement/Control, Natural, Haptic, Resolution and the Total Score had significant differences ($p<0.05$).

Table 5-3. The ANOVA table on PQ scores from Experiment 1

PQ subscales	Sources	Sum of Squares	df	Mean Square	F	Sig.
Involved/control	Experimental Environments	477.5	3	159.167	4.029	0.013
	Error	1738.167	44	39.504		
	Total	2215.667	47			
Natural	Experimental Environments	122.729	3	40.91	7.508	0
	Error	239.75	44	5.449		
	Total	362.479	47			
Interface Quality	Experimental Environments	22.229	3	7.41	1.497	0.228
	Error	217.75	44	4.949		
	Total	239.979	47			
Auditory	Experimental Environments	25.75	3	8.583	1.832	0.155
	Error	206.167	44	4.686		
	Total	231.917	47			
Haptic	Experimental Environments	115.396	3	38.465	7.627	0
	Error	221.917	44	5.044		
	Total	337.313	47			
Resolution	Experimental Environments	49.396	3	16.465	3.982	0.014
	Error	181.917	44	4.134		
	Total	231.312	47			
Total score	Experimental Environments	1593.729	3	531.243	6.119	0.001
	Error	3820.25	44	86.824		
	Total	5413.979	47			

Table 5-4 which shows the Student-Newman-Keuls (SNK) result and in which that the Total Score from the RE_weight, RE_restricted and TE were within the same group which was significantly higher than the group formed by scores from the TE and VE ($p < 0.05$).

Table 5-4. The Student-Newman-Keuls (SNK) result on the PQ Total Score collected from the participants in Experiment 1 (in ascending order of the mean value)

Experimental environments	*Group 1*	*Group 2*
VE	73.42	
TE	78.83	78.83
RE_weight		86
RE_restricted		87.83

The causes to the lowest PQ score in VE were due to that participants in the VE rated the involved/control, natural and haptic significantly lower than the other 3 experimental environments ($p<0.05$). This could be explained as that VE provided the most unnatural interface to the participants (see Table 5-2). The participants at TE perceived second least sense of presence could be mainly due to the large imposed lag. It was illustrated from Figure 5-3 that all the PQ subscales rated by the participants in TE were just slightly higher than VE except resolution. For the resolution subscale, TE was the lowest one. In PQ there were only 2 questions counted for resolution. These 2 questions are "Q15: how closely was the participant able to examine objects" and "Q16: how well to examine objects from multiple viewpoint". In the first question, the mean score of TE was 3 while the mean score of VE was 4. In the second question about the multiple viewpoints, both TE and VE had the mean score of 3.6. This indicated that participants in TE had the difficulty on closely examining objects. The reasons which caused the difficulties of the participants in TE to observe the objects were due to the setup of the TE environment, such as the equipment noises (e.g. cable, cable conjunctions, the V4 connector) and the double images caused by asynchronization

between the computer sent out the images and the V4 head-mount-display intake.

5.7. Discussions on the results of Experiment 1

5.7.1. The testing of the hypothesis

There was a significant difference shown in the Presence Questionnaire (PQ) Total Score in the SNK table (see Table 5-4). Therefore it indicated that PQ could differentiate the level of sense-of-presence (SOP) that the participants experienced from real to virtual environments, and this result was against the hypothesis stated in Section 5.4.

5.7.2. Observed problems with the answers to the 18 questions in the Presence Questionnaire (PQ) from participants of the real environment without restricted field-of-view but with head-mounted weight (RE_weight)

There were 18 questions from the Presence Questionnaire (PQ) should provide extreme position ratings in the real environment without restricted field-of-view but with head-mounted weight (RE_weight). The details of these 18 questions were listed in Appendix 5.1. When further inspections on the raw scores of these 18 questions in RE_weight, problems associated with

them were observed. Figure 5-4 illustrated the distribution of the responses of these 18 questions from RE_weight.

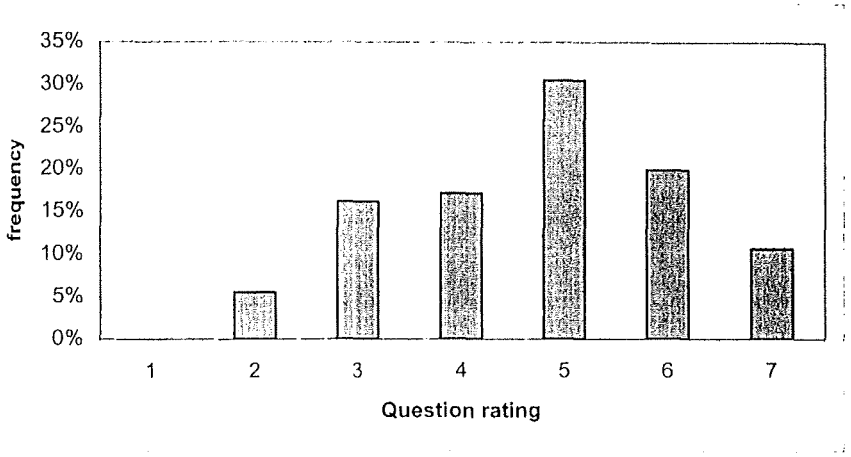

Figure 5-4. The distribution of the responses of the 18 questions from the PQ rating (1-7) from the RE_weight participants in percentage from the 48 sets of data in Experiment 1.

Observations from the distribution (shown in Figure 5-4) shows that the peak occurs on rating-5 and it takes more than 30% of the all responses of the selected 18 questions. In addition, there are 0% on rating-1 and only 10% on rating-7. This means that there were only 10% of these 18 PQ questions were the extreme position ratings. However, participants in RE_weight should provide extreme position ratings on these selected 18 PQ questions, why would there only be 10% extreme position ratings occur?

Further inspections suggested 2 probabilities on this occurrence. One reason was that the participants in RE_weight misunderstood and confused the questions and hence chose the rating which did not represent what they

experienced. Secondly the participants were reluctant to choose the end ratings. The following section illustrated these problems.

The participants in RE_weight environment did not consider the questions as the way that the questions were designed. For example in question 19, the whole question is "How much delay did you experience between your actions and expected outcomes?". The scale of this question was rating-1: no delays, 4: moderate delay and 7: long delays. The response rate is 41.7% chose rating-5 and 33.3% chose rating-6 which means 75% of RE_weight participants consider there were delays in a real environment. However when interviewing them afterward, we found out that the participants consider the term of "delays" as the time spent on thinking, while the "delays" should be the time delay of movement.

In addition, uncertainty could also be caused by the effect of questionnaire on certain environment. When the participants were presented in the real environment, they might know that there was no delay at all however they adjusted themselves to the questions or reluctant to choose the end rating (i.e. rating-7 or rating-1). This was also seen in question 19, there were 2% of responses in RE_weight were rating-2 which was just slightly more than no delays. Another example was in the Q11 "How well could you identify

sound?" 50% of the responses from the VE were rating-6 which is one rating behind rating-7 "completely. Given that the audio quality for all experimental environments were the same and their performance on sound localisation were completely correct.

5.8. Summary of Experiment 1

Although PQ could differentiate the differences between the level of sense-of-presence (SOP) experienced by the participants from real and virtual environments. The existing Presence Questionnaire caused the participants avoided choosing the extreme position ratings and this problem was illustrated by the raw scores of the 18 questions where extreme position ratings should be occurred in the RE_weight condition. A cable-free real environment would be constructed in the next experiment in order to eliminate the effect of the headset weight effect of the level of SOP participants experienced in a real environment.

CHAPTER 6

PROBLEM IDENTIFICATION AND PROPOSED SOLUTIONS

6.1. Problem identification

In this section, problems which were found when using the existing presence questionnaires to measure the level of sense-of-presence (SOP) that participants experienced in environments other than the virtual environments were summarized.

6.1.1. Review on study done by Usoh and his colleagues on applying the existing presence questionnaires on measuring level of sense-of-presence (SOP) which experienced in real and virtual environments

In Usoh et al. (2000), two sets of presence questionnaires were applied to measure level of sense-of-presence (SOP) that participants experienced in the real and its corresponding virtual offices. The questionnaires which were used were the Presence Questionnaire (PQ, Witmer and Singer, 1996) and the Slater-Usoh-Steed questionnaire (SUS). The SUS questionnaire was developed by Dr. Slater, Dr. Usoh and Dr. Steed to measure SOP that participants experienced in the environments. The SUS questionnaire consists of six Likert scale 7-pont rating questions and 2 open questions. One of those rating questions required participants to directly their "sense of

being" in the office. 10 participants were assigned to real office and 10 participants in its corresponding virtual office. Participants in that study were asked to perform some searching tasks and then those 2 sets of questionnaire were given in random order. From this study, the result shows that SUS questionnaire questions could marginally differentiate the level of SOP that reported from real and virtual environments ($p<0.1$) but PQ did not differentiate the SOP from real and virtual environments at all ($p>0.05$). The suspected reason for this was that low rating responses were collected in both questionnaires. In addition, participants who carried out tasks in the real office reinterpreted the meaning of "being there" as "the degree of involvement or lack of alienation in the environment", this shows the differences between the actual questionnaire meaning and the way that the participants' interpretations of this. From this study, it also raised some doubts on the utility of existing presence questionnaires used across different environments.

6.1.2. Problem identifications from Experiment 1 results

Experiment 1 was conducted in order to testify whether PQ could differentiate the level of SOP experienced by the participants in real and virtual environments. Results showed that the level of SOP measured by PQ in real environment was significantly higher than in virtual environment, details of this result was shown in Section 5.8. Further investigations showed that participants tended to avoid choosing the extreme position ratings, rating -1 and rating-7, in the Likert scale 7-point rating. This was due to the participants confused and misunderstood certain questions

6.2. Proposed solution: Presented the Presence Questionnaire (PQ) in Cooper-Harper rating style - Cooper-Harper rating Presence Questionnaire (CHRPQ)

As the rating style and wording were the suspected causes for the problems stated in Section 6.1, the Cooper-Harper rating was adapted to present the Presence Questionnaire (PQ). Cooper-Harper rating was developed in 1969 for evaluation of aircraft handling qualities (Figure 6-1). The purposes of adapting this rating method were this rating method was able to clarify questions to participants and also avoid participants choosing the middle point rating.

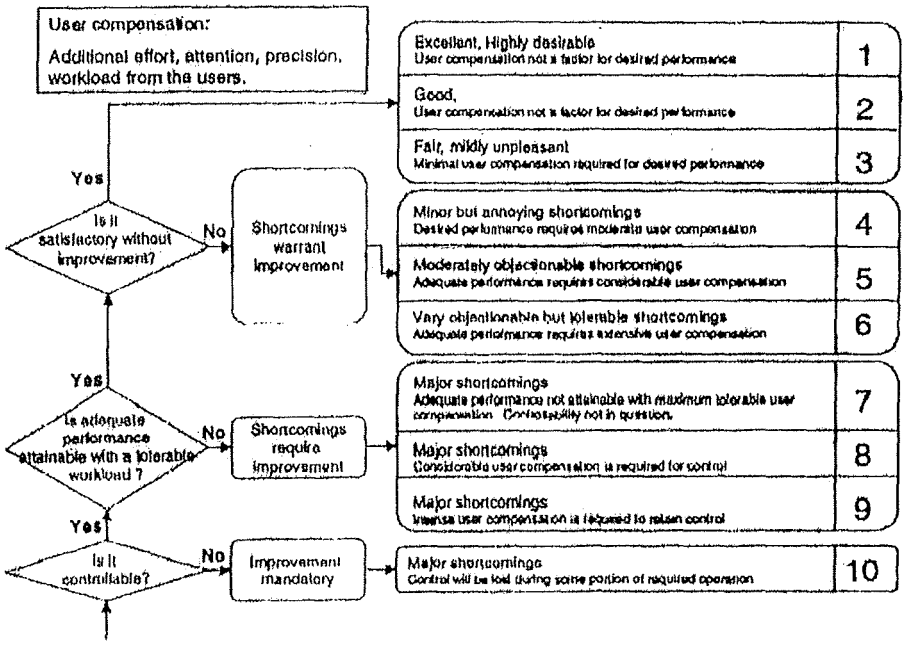

Figure 6-1 The Cooper-Harper rating used in the original aircraft handling qualities evulations.

The Presence Questionnaire presented in Cooper-Harper rating style, Cooper-Harper rating Presence Questionnaire (CHRPQ), was a computer-based questionnaire and certain questions had examples or Chinese translations to list out with. The final ratings of each question would not be shown to the participants. The details of the whole questionnaire were listed in Appendix 2.1c.

The following of section explained the question structure in Cooper-Harper rating style:

(1) For each CHRPQ question, the original question from PQ was listed out at the beginning as the overall question. This was listed in order to let the participants have some general ideas on what the whole question about, and then followed by

(2) The overall question was later derived into directional and tendency questions. The directional question was Yes/No question or agree/disagree statement. These sub-question(s) and statement(s) in each question were constructed to avoid middle-point being chosen

(3) After a direction was chosen, participants would choose their adequate degree towards that direction

6.3. Proposed another set of questionnaire to measure the subjective sense-of-presence (SOP): Slater's Questionnaire presented in Cooper-Harper rating style (Cooper-Harper rating Slater's Questionnaire, CHRSQ)

CHRSQ is the Slater's Questions presented in Cooper-Harper rating style. The Slater's Questionnaire is a set of questions collected from past researches on the SOP conducted by Dr Slater and his colleagues and the details of the Slater's Questionnaire was listed in Appendix 2.2a. The details

of Cooper-Harper rating Slater's Questionnaire were listed in Appendix 2.2b. The CHRSQ is also a computer-based questionnaire. Certain questions had examples or Chinese translations to list out with the original questions which made the participants easier to understand the questions. The ratings of the questions would not be shown to the participants.

CHAPTER 7

EXPERIMENT 2: VALIDATE THE USABILITY OF THE PRESENCE QUESTIONNAIRE PRESENTED IN COOPER-HARPER STYLE (CHRPQ)

7.1 Introduction

Lessons learnt from Experiment 1

(i) There was a possible effect of the cabling and headset weight on the subject level of sense-of-presence (SOP) that participants experienced in the experimental environments. As mentioned in the Discussion Section 5.8.3, a real environment that without headset and cabling is needed. This new experimental environment would be introduced in this Experiment 2 and was called as the real environment (RE).

(ii)When the participants were filling in the Presence Questionnaire (PQ), they sometimes re-interpreted the questions' meanings different from the original and also reluctant on choosing the extreme positions ratings (i.e. rating -1 and rating -7) from a Likert-scale 7-point rating in places where they should occur and these problems were illustrated in Appendix 5.1. In order to solve this problem, the Presence Questionnaire presented in the Cooper-Harper style (Cooper-Harper rating Presence Questionnaire, CHRPQ) was developed. The introduction of this questionnaire was listed

in Chapter 3 and the whole CHRPQ was listed in Appendix 2.1c.

7.2 Objectives

The objective of this experiment is to validate the usability of the Presence Questionnaire presented in Cooper-Harper rating style in both the real and virtual environments.

7.3 Experimental design

There were four experimental environments in this experiment which were constructed to achieve the objective. These four environments were the real environment (RE), the real environment with a head-mounted weight but no restricted field-of-view (RE_weight), the real environment viewed through a headset of restricted field-of-view (RE_weight) and the virtual environment (VE). Other than the RE, the other three experimental environments were the same as the environments used in Experiment 1. The details of these experimental environments were listed in Section 4.3.2.

Full factorial randomized design was applied here. There were 48 male participants randomly assigned to the experimental environments, with 12 replications (participants) for each experimental environment. All of these participants were Hong Kong Chinese, right-handed, had normal or corrected to normal eyesight and did not have colorblindness.

7.4 Hypotheses

H2-1 The Presence Questionnaire presented in Cooper-Harper style (Cooper-Harper rating Presence Questionnaire, CHRPQ) score provided by the participants from the real environment (RE) would be the highest compared with the other 3 experimental environments as the RE was same as a room in the real world. The score value of the CHRPQ would be decreased from RE_weight to RE_restricted and the participants at the VE would provide the lowest rating.

H2-2 More extreme positions ratings would be occurred in the RE_weight than the RE_weight of the Experiment 1. This comparison was only conducted on the selected 18 questions responses, these 18 selected questions were the questions were extreme positions ratings should occurred in the RE_weight. The details of these selected questions were described in Appendix 5.1.

H2-3 Higher level of significant in the differences between the PQ scores which were obtained in the VE and RE_weight conditions in Experiment 2 than Experiment 1

H2-4 Peripherals such as headset weight and cabling would have effect on individual's sense-of-presence (SOP) ratings

7.5 Procedure and tasks

The tasks that the participants were asked to perform inside the assigned experimental environments were the visual search task and moving cylinder task. The details of these 2 tasks were described in Section 4.2.1.3. The procedure of the whole experiment was same as in Experiment 1 and listed in the Section 5.4.

7.6 Results

7.6.1 Reliability of the Presence Questionnaire presented in the Cooper-Harper rating style (CHRPQ)

Cronbach's alpha test was used to measure the internal consistency of the Presence Questionnaire presented in Cooper-Harper rating style. This test was performed on the responses of the 19 questions which were counted for the total score of CHRPQ. The resultant alpha value is 0.88 which exceeded 0.8 and hence considered CHRPQ was a good measurement device (Breakwell, 1995).

7.6.2 Effect of experimental environments on the subjective level of sense-of- presence (SOP) which was measured by the CHRPQ

The subjective rating of sense-of-presence (SOP) decreased steadily from RE to VE and the descending order is RE, RE_weight, RE_restricted, VE.

One can see from Figure 7-1, participants in the RE reported the highest level of SOP.

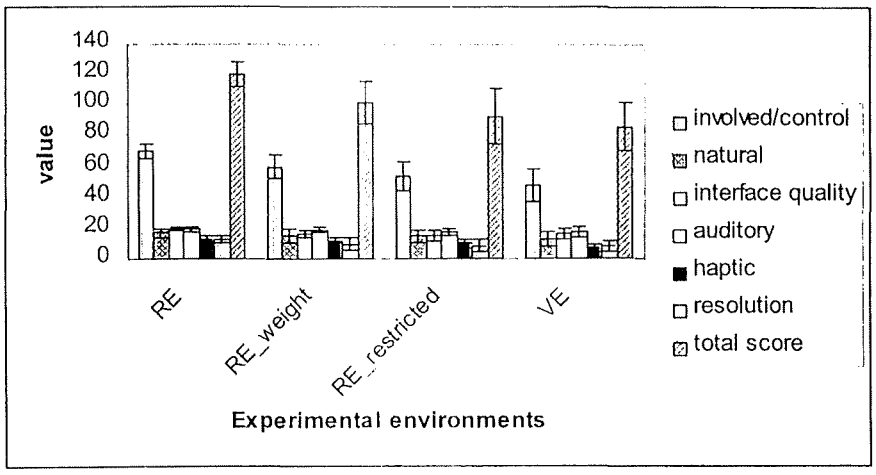

Figure 7-1 Mean values of CHRPQ subscales and theTotal Score among the four experimental environments, RE, RE_weight, RE_restricted and VE in experiment 3. Bars denote means one standard deviation. The CHRPQ subscales included the involved/control, natural, interface quality, auditory, haptic and resolution.

There was significant effect of experimental environments on the level of sense-of-presence (SOP) that the participants experienced (Table 7-1). Student- Newman-Keuls (SNK) post-hoc test was conducted over CHRPQ Total Score, result (Table 7-2) shows that RE was statistically significant higher from RE, RE_restricted and VE ($p<0.05$). RE_weight was significant different from VE ($p<0.05$). There were no significant differences between RE_weight and RE_restricted and also no significant differences between RE_restricted and VE.

Table 7-1 The summary of ANOVA on the effects of experimental environment on the CHRPQ subscales and the total score in Experiment 2.

PQ subscales and total score	*Sources*	*Sum of Squares*	*df*	*Mean Square*	*F-value*	*Sig.*
Involve/control	Experimental environments	3140.396	3	1046.799	15.371	.000
	Error	2996.583	44	68.104		
	Total	6136.979	47			
Natural	Experimental environments	120.229	3	40.076	2.238	.097
	Error	787.750	44	17.903		
	Total	907.979	47			
Interface Quality	Experimental environments	177.896	3	59.299	6.638	.001
	Error	393.083	44	8.934		
	Total	570.979	47			
Auditory	Experimental environments	44.750	3	14.917	2.494	.072
	Error	263.167	44	5.981		
	Total	307.917	47			
Haptic	Experimental environments	255.729	3	85.243	14.421	.000
	Error	260.083	44	5.911		
	Total	515.813	47			
Resolution	Experimental environments	151.396	3	50.465	4.259	.010
	Error	521.417	44	11.850		
	Total	672.812	47			
Total Score	Experimental environments	8110.833	3	2703.611	12.670	.000
	Error	9388.833	44	213.383		
	Total	17499.667	47			

Table 7-2 The Student-Newman-Keuls (SNK) grouping of experimental environments on CHRPQ Total Score in experiment 2. Means for groups in homogeneous subsets are displayed. The subsets were tested at 5% level.

	Subsets		
Experimental environments	1	2	3
VE	85.75		
RE_restricted	92.67	92.67	
RE_weight		101.50	
RE			120.42

7.6.3 The results of the 18 selected questions which responses should be resulted in extreme positions ratings in RE_weight

The percentage of the extreme and middle positions ratings occurred in the 18 selected questions in the RE_weight in this experiment is shown in Table 7-3. The 18 selected questions were the questions which responses should be resulted in extreme position ratings. The descriptions of these 18 selected questions were listed in Appendix 5.1. The combined percentage of the extreme positions ratings in the RE_weight in Experiment 2 was 53% which was larger than the occurrence percentage of the middle-position rating a lot.

Table 7-3. Percentage of the extreme positions ratings (i.e. rating-1 and 7) and middle-position (i.e. rating-4) of the CHRPQ occurred in the responses given by the participants who were assigned to the RE_weight environment in Experiment 2.

	Extreme positions ratings		*Middle-position rating*
	Rating-1	*Rating-7*	*Rating-4*
RE_weight	12%	41%	5%

7.7 Discussions

7.7.1 Testing of the hypothesis

7.7.1.1 Testing of Hypothesis 1: the order of the level of sense-of-presence (SOP) that participants experienced inside the experimental environments.

From the result, Section 7.6.2, the level of sense-of-presence (SOP) that participants experienced was increased from VE to RE_restricted to RE_weight and the participants in the RE had the highest rating of the SOP. This result agreed with the hypothesis (H2-1) stated in Section 7.4. Furthermore the level of SOP rated in RE was significantly higher than the other 3 experimental environments ($p<0.05$).

However, there was no significant difference between RE_weight and RE_restricted ($p>0.05$) which implied that restricted the participants' field-of-view (FOV) had no effect on experiencing the sense-of-presence (SOP). It was possibly due to the task that the participants performed did not let them notice inconvenient of the restricted FOV.

Other than the sensory interface could affect the sense of presence, the time effect on sense of presence and also how fast the participants adjusted to the environments could also be significant factors to the measurement of presence. As one could notice that participants shared the same level of

SOP in RE_restricted and VE even though VE had lower sensory interface level than RE_restricted (see Chapter 4 for the setup of the experimental environments), such as in display resolution, imposed time delay and sense of touch. This did not mean that the degradation of the sensory variables had no effect on the SOP that participants experienced. However the effect may be happen in the early stage of the experience, and after awhile this effect may have fade away as the participants have already well adjusted to the environments. As a result the effects of sensory variables did not show at all. When inspecting one of the questions from CHRPQ, question 20 on the how fast the participants could adjust to the environments. There was no significant differences among the experimental environments ($p>0.05$). This indicated that all of the participants could adjust quite easily to the environments and adapted the environments that they experienced as the places that they existed.

7.7.1.2 Testing of Hypothesis 2: Compare the extreme positions ratings in the places where they should occur in the RE_weight between the Experiment 1 and Experiment 2.

Table 7-4 shows the percentage of extreme positions ratings occurrence of the selected 18 questions in the RE_weight from both Experiment 1 and Experiment 2. The selected 18 questions were the questions which responses should be the extreme positions and they were explained in the Appendix 5.1. The occurrence of the extreme position rating in the selected 18 questions of the RE_weight in Experiment 2 was higher than the occurrence in Experiment 1. Furthermore the middle position rating in the RE-weight of Experiment 2 was less than in Experiment 1. This demonstrates that the Cooper-Harper rating style could successfully reduce the incident of the participants avoiding to choose the middle position ratings. Further statistical analysis was conducted to confirm this subject. Before conducting the statistical analysis, the original ratings were recoded and the rules for recoding were listed in Table 7-4. The usage of this coding was to prepare the later statistical analysis on comparing the frequency of extreme positions ratings between Experiment 1 and Experiment 2. In order words, it was the comparison between the extreme positions ratings occurrence in the original Likert scale 7-point rating and the Cooper-Harper rating style.

Table 7-4 The coding method which was used before the statistical analysis was performed.:

Original response value	After coded value
1	1
2	2
3	3
4	4
5	3
6	2
7	1

Mann-Whitney test was performed on the coded value to compare the appearance frequency of extreme position ratings of the original PQ in Experiment 1 and CHRPQ used in Experiment 2. This test was only performed on the datum which was from the 18 selected questions of the RE_weight. The result of the Mann-Whitney test is shown in Table 7-5.

Table 7-5 The Mann-Whitney test on the frequency of extreme position ratings in the 18 selected questions' responses of the original PQ and CHRPQ from the RE_weight. The grey rows indicated the question where significant difference in the responses was occurred ($p<0.05$).

The selected 18 questions	Chi-Square	df	Asymp. Sig.
Q1	2.413	1	0.12
Q2	0.044	1	0.83
Q3	9.336	1	0.00
Q6	15.165	1	0.00
Q8	1.121	1	0.29
Q9	3.42	1	0.06
Q10	7.518	1	0.01
Q11	2.573	1	0.11
Q12	1.344	1	0.25
Q13	4.01	1	0.05
Q15	12.108	1	0.00
Q16	7.616	1	0.01
Q17	7.486	1	0.01
Q19	20.288	1	0.00
Q22	12.602	1	0.00
Q23	0.548	1	0.46
Q29	10.404	1	0.00
Q31	15.207	1	0.00

Table 7-5 shows that there were two-third of the responses on the questions where extreme position ratings should be occurred were significantly different ($p<0.05$). Therefore it further confirmed that Cooper-Harper rating could enable the participants to choose the extreme position ratings in the questions where this phenomenon should be observed. In addition, as the participants were less reluctant to choose the middle position rating while filling the PQ which was presented in Cooper-Harper rating format, the scores collected in Experiment 2 was higher than in Experiment, see Table 7-6 for illustration. This result also increased the total score of the PQ indirectly as 17 out of these 18 selected questions were included in the 19 questions which were counted for the total score.

Table 7-6 Comparison of the mean values of the selected 18 questions ratings from the RE_weight collected from the Experiment 1 and Experiment 2. The grey rows indicate the questions where significant differences were occurred in the responses ($p<0.05$)

The selected 18 questions where extreme positions should be occurred	Mean ratings collected from the RE_weight by using the Likert scale 7-point rating Presence Questionnaire in the Experiment 1	Mean ratings collected from the RE_weight by using the Presence Questionnaire presented in the Cooper-Harper rating style in the Experiment 2
Q1	4.75	5.67
Q2	3.83	5.50
Q3	4.75	5.42
Q6	4.25	4.92
Q8	4.58	5.25
Q9	4.83	6.00
Q10	4.83	5.83
Q11	6.42	6.75
Q12	6.42	6.50
Q13	5.58	6.08
Q15	4.92	5.00
Q16	4.25	4.67
Q17	4.58	6.17
Q19	4.50	7.00
Q22	4.42	6.58
Q23	4.50	3.67
Q29	4.83	6.33
Q31	5.08	7.00

7.7.1.3 Testing of Hypothesis 3: Higher level of significant in the differences between the PQ scores obtained in the RE_weight and VE conditions in this experiment than in Experiment 1.

Further testing was conducted on verifying H2-3. Mann-Whitney test was performed on comparing the level of differences between the PQ total score collected from RE_weight and VE conditions' participants in both Experiment 1 and 2 and its result was listed in Table 7-7. If the absolute Z-value is large, it implied that the differences between the PQ total scores collected from the RE_weight and VE were large and vice versa. Observations of the Z-values in Table 7-7, the absolute Z-value of the Experiment 1 was larger than the Experiment 2 which indicated that the difference of PQ total score between RE_weight and VE in Experiment 1 was larger than in Experiment 2.

Table 7-7 The Mann-Whitney test summary on the total score of PQ obtained from the RE_weight and VE in Experiments 1 and 2

Sources	Compare the PQ Total Score obtained from the RE_weight and VE in Experiment 1	Compare the PQ Total Score obtained from the RE_weight and VE in Experiment 2
Mann-Whitney U	26.00	39.50
Wilcoxon W	104.00	117.50
Z	-2.662	-1.878
Asymp. Sig (2-tailed)	0.008	0.06

This result against the hypothesis H2-3 stated in Section 7.4. Discussion in Section 7.7.1.2 shows that the Cooper-Harper format question can increase the rating score significantly in RE_weight, but the fact could be that the Cooper-Harper format question also increase the score in the experimental environments other than RE_weight such as VE. A Mann-Whitney test was

conducted on comparing the PQ total score obtained from RE_weight in Experiment 1 and Experiment 2 and same test was also conducted on the PQ total score obtained from VE in Experiments 1 and 2, the result of this analysis was shown in Table 7-8. From Table 7-8, large significant difference in the PQ Total between RE_weight in Experiment 1 and RE_weight in this experiment (i.e. Experiment 2) was observed with Z-value =-2.543. However the level of significant difference between VE in Experiment 1 and this experiment was just marginal ($p<0.1$) and with Z-value=-1.676. This result showed that the Cooper-Harper Technique had significant effect on VE PQ scoring. The Table 7-9 shows the mean values of the PQ questions' ratings, which were responsible for the total score, collected from the VE in the Experiment 1 and Experiment 2, inspections from this shown that 42% of the ratings were affected by the Cooper-Harper technique and the effect was mostly increasing the ratings. Table 7-10 shows the questions whose ratings were calculated as the PQ total score were also increased significantly ($p<0.05$) by presenting the questions in Cooper-Harper technique. Table 7-10 also shows that 58% of the ratings of the total score were increased, therefore the percentage of ratings increased in RE_weight from Experiment 1 to Experiment 2 was 16% more than the percentage in VE from Experiment 1 to Experiment 2. This further implied that the increasing level in the ratings obtained from RE_weight from Experiment 1 to Experiment 2 was larger than obtained from the VE. Due to VE and RE had different level of increasing in the ratings from Experiment 1 to Experiment 2, the level of significant in the differences between the PQ scores obtained in the RE_weight and VE conditions in this experiment becomes unnoticeable.

Table 7-8 A summary of Mann-Whitney test conducted on comparing the PQ total score collected from RE_weight in Experiments 1 and 2, and also comparing the PQ total score collected from VE in Experiments 1 and 2

Sources	Compare the PQ total score collected from VE in Experiment 1 and 2	Compare the PQ total score collected from the RE_weight in Experiment 1 and 2
Mann-Whitney U	43.00	28.00
Wilcoxon W	121.00	106.00
Z	-1.676	-2.543
Asymp. Sig. (2-tailed)	0.094	0.011

Table 7-9 The mean and standard deviations of the ratings of the questions which were counted to the Total score and obtained from the VE in Experiment 1 and Experiment 2. In addition with the p-values were stated on showing the level of significant differences between the scorings of these questions from the VE in Experiment 1 and Experiment 2. The grey rows indicated the significant differences between the ratings.

Questions	Mean value of the question rating obtained from the VE in the Experiment 1	Standard deviation of the question rating obtained from the VE in the Experiment 1	Mean value of the question rating obtained from the VE in the Experiment 2	Standard deviation of the question rating obtained from the VE in the Experiment 2	Changes from Experiment 1 to Experiment 2	Sig. level
q1	3.33	1.30	5.00	1.71	increased	<0.05
q2	4.17	1.27	4.17	1.70	unchanged	>0.05
q3	3.00	0.95	4.42	2.23	Increased	<0.1
q4	4.17	0.72	5.08	1.56	increased	<0.05
q6	3.17	1.11	4.92	1.51	Increased	<0.01
q7	3.42	0.90	3.50	2.65	Decreased	>0.05
q8	3.25	0.75	3.50	2.35	Increased	>0.05
q9	3.42	1.44	4.33	1.87	Increased	>0.05
q10	4.25	0.97	4.50	2.02	Increased	>0.05
q14	4.33	0.98	4.50	2.02	Increased	>0.05
q15	4.00	1.41	3.50	2.20	Decreased	>0.05
q16	3.58	1.00	5.08	1.78	Increased	<0.05
q18	4.75	1.14	5.33	0.98	Increased	>0.05
q19	3.92	1.56	5.58	1.24	Increased	<0.01
q20	4.00	1.35	4.75	2.34	Increased	>0.05
q21	3.83	1.11	1.33	0.65	Decreased	<0.00
q22	4.17	1.27	6.33	1.30	Increased	<0.00
q23	4.33	1.07	3.92	2.47	Decreased	>0.05
q24	4.33	1.23	6.00	1.65	Increased	<0.01

Table 7-10 The mean and standard deviations of the ratings of the questions which were counted to the Total score and obtained from the RE_weight in Experiment 1 and Experiment 2. In addition with the p-values were stated on showing the level of significant differences between the scorings of these questions from the VE in Experiment 1 and Experiment 2. The grey rows indicated the significant differences between the ratings.

Questions	Mean value of the question rating obtained from the RE_weight in the Experiment 1	Standard deviation of the question rating obtained from the RE_weight in the Experiment 1	Mean value of the question rating obtained from the RE_weight in the Experiment 2	Standard deviation of the question rating obtained from the RE_weight in the Experiment 2	Changes from Experiment 1 to Experiment 2	Sig. level
q1	4.83	1.27	5.67	1.37	Increased	>0.05
q2	4.75	1.66	5.50	1.57	Increased	>0.05
q3	3.75	1.22	5.42	2.02	Increased	<0.05
q4	4.42	1.24	6.00	1.28	Increased	<0.01
q6	4.25	0.97	4.92	2.43	Increased	<0.1
q7	4.42	1.24	5.83	1.53	Increased	<0.05
q8	4.83	1.70	5.25	2.01	Increased	>0.05
q9	4.67	1.50	6.00	0.95	Increased	<0.05
q10	4.67	1.15	5.83	1.11	Increased	<0.05
q14	4.25	0.75	6.08	1.24	Increased	<0.01
q15	4.33	1.30	5.00	2.49	Increased	>0.05
q16	4.83	1.03	4.67	2.31	Decreased	>0.05
q18	5.17	1.03	6.25	0.75	Increased	<0.05
q19	4.83	1.27	7.00	0.00	Increased	<0.01
q20	4.92	1.62	3.83	2.66	Decreased	>0.05
q21	4.67	0.65	1.83	1.59	Decreased	<0.01
q22	3.67	1.23	6.58	0.79	Increased	<0.01
q23	4.08	1.24	3.67	1.56	Decreased	>0.05
q24	4.67	1.44	6.17	1.64	Increased	<0.05

Investigations were conducted over the questions which shown significant changes in Table 7-9, several explanations on why these changes occurred were explained as below.

There were 2 main reasons for this, firstly it was the examples of the questions which lead the participants to consider several specific occasions instead of the general picture and secondly the anchoring of the statement

which lead to middle position rating. The first reason related to the examples restricting the participants' thinking could be illustrated in the Q1 which is listed in Appendix 2.1a. The examples of controlling events were listed as moving objects and selecting viewpoints, participants in VE may rate this question by just considering these 2 examples and ignore the original question. As the participants in VE could finish the movements mentioned in those 2 examples easily, they rated this question higher than the participants did in the Experiment 1. Therefore the ratings of this question may be less representative than the ratings of this question in Experiment 1 under the same condition.

Another reason was the setting of the middle position and this can be illustrated in Q6 which was listed in Appendix 2.1c. In this question, the format was putting the middle position belong with the low rating group (i.e. rating 2 and rating 3). Therefore when the participants wanted to choose the middle-point but by choosing the higher rating group (i.e. rating-5, rating-6 and rating-7) at the beginning, they could not choose the middle-point (rating-4) and in result they chose rating-5 statement which has the closest meaning to the statement of rating-4. In other words, the value of the rating was raised from 4 to 5.

However there was also benefit on using the Cooper-Harper Technique to present the questions in PQ. For example in Q3 which was about the participants' feelings towards the level of the naturalness of their actions in the experimental environments. For this question one would expected that there would be significant differences between the ratings obtained from RE_weight and VE. However the ratings were insignificant differences between RE_weight and VE in Experiment 1 using the PQ preented with

Likert scales ($p>0.05$, Table 7-11), the mean value of this question rating in RE is 3.75 with standard deviation of 1.22 and the mean value of the VE is 3 with standard deviation of 0.95. This means that the participants were tended to choose the middle position ratings. In the Experiment 2 (this experiment), the Cooper-Harper technique was adapted to present this question and it became significant differences on ratings in this question as shown in Table 7-12. In Experiment 2 the mean value of Q3 obtained from VE is 4.42 which implied that the participants in VE could interact with the environments in quite a natural way but not as good as in the real world, and the mean rating obtained from RE_weight was 5.42 which means that participants felt their interactions in the environment was more or less same as the way they had in the real word. This example shows that Cooper-Harper technique could encourage the participants to choose the extreme ratings in the places that these ratings should be occurred. Another example such as Q19 also shows the benefit of using the Cooper-Harper technique on presenting the question. Question 19 is related to the level of time delay that the participants noticed when exposed to the environments. In this question, a significant difference was expected between the ratings of RE_weight and VE as there was imposed time delay implemented in VE but none in RE_weight. However there was no significant difference occurred between the ratings from the participants in RE_weight and VE in Experiment 1 ($p>0.05$, Table 7-11). By using the Cooper-Harper presentation style on this question in Experiment 2, there was a large significant difference between the ratings of Q3 in RE_weight and VE was found ($p<0.01$).

Table 7-11 A summary of Mann-Whitney test on comparing the PQ questions' scores obtained from RE_weight and VE in Experiment 1. The tested ratings were obtained from ratings of the which were counted for the PQ total score

Questions	Mann-Whitney U	Wilcoxon W	Z	p-value)
Q1	31	109	-2.419	0.016
Q2	55	133	-1.001	0.317
Q3	45.5	123.5	-1.609	0.108
Q4	67	145	-0.305	0.76
Q6	34	112	-2.274	0.023
Q7	36	114	-2.17	0.03
Q8	35.5	113.5	-2.305	0.021
Q9	39.5	117.5	-1.91	0.056
Q10	57.5	135.5	-0.875	0.381
Q14	68	146	-0.246	0.806
Q15	60	138	-0.708	0.479
Q16	28.5	106.5	-2.589	0.01
Q18	58.5	136.5	-0.814	0.416
Q19	43.5	121.5	-1.701	0.089
Q20	46	124	-1.533	0.125
Q21	37.5	115.5	-2.092	0.036
Q22	57	135	-0.89	0.373
Q23	61.5	139.5	-0.629	0.529
Q24	61	139	-0.657	0.511

Table 7-12 A summary of Mann-Whitney test on comparing the PQ questions' scores obtained from RE_weight and VE in Experiment 2. The tested ratings were obtained from ratings of the which were counted for the PQ total score.

Questions	Mann-Whitney U	Wilcoxon W	Z	p-value
Q1	54.5	132.5	-1.037	0.3
Q2	36.5	114.5	-2.096	0.036
Q3	49	127	-1.377	0.169
Q4	43	121	-1.748	0.08
Q6	54.5	132.5	-1.061	0.289
Q7	34	112	-2.259	0.024
Q8	41.5	119.5	-1.809	0.07
Q9	30	108	-2.518	0.012
Q10	41	119	-1.92	0.055
Q14	34	112	-2.262	0.024
Q15	42.5	120.5	-1.764	0.078
Q16	65	143	-0.428	0.669
Q18	34.5	112.5	-2.337	0.019
Q19	24	102	-3.338	0.001
Q20	59	137	-0.776	0.438
Q21	68	146	-0.304	0.761
Q22	69.5	147.5	-0.19	0.849
Q23	66	144	-0.358	0.72
Q24	67	145	-0.36	0.719

7.7.1.4 Testing of Hypothesis 4: Peripherals lowered subjective sense-of-presence (SOP)

Inspection of the SNK result (Table 7-2) on the CHRPQ total score, peripherals had significant effect on the level of sense-of-presence that the participants experienced ($p<0.05$). In addition, this effect was negative which implied that peripheral lowered the level of SOP that participants experienced significantly. This result was also found in the Usoh (2000) which found that cabling decrease participants' SOP.

7.7.2 Notes on using the Presence Questionnaire presented in Cooper-Harper rating style (CHRPQ)

The Presence Questionnaire presented in Cooper Harper rating passed the 'reality' test and hence usable on measuring the subjective level of sense-of-presence (SOP) that participants experienced in both real and environments. However, by using Cooper-Harper rating style, the answering time was elongated. In addition, the occurrence of double-negative questions in the CHRPQ could confuse the participants. Therefore a modified version of CHRPQ was needed and the modified version was illustrated in Appendix 2.1d and used in the Experiment 3. However when using the PQ presented in Cooper-Harper rating style should be noted that sometimes the participants did not give out the ratings of their actual feelings towards the

original questions but towards the examples that shown with the original questions instead.

7.8 Summary

Cooper-Harper question format was successfully adapted and used in presenting the Presence Questionnaire. By using the Cooper-Harper presentation, the problems of participants avoiding choosing the extreme positions ratings and misunderstood the questions were solved. With the success of adapting the Cooper-Harper question format to the Presence Questionnaire, this question presentation style was also adapted to the Slater's Questionnaire (Appendix 2.2b) and the Slater's Questionnaire presented in Cooper Harper style (Appendix 2.2c) was developed and used. Both questionnaires, the Presence Questionnaire presented in Cooper-Harper style and the Slater's Questionnaire presented in Cooper-Harper style, were used in Experiment 3 to measure the subjective level of sense-of-presence (SOP) of the participants.

CHAPTER 8

Experiment 3- Study The Relationships Among Sense-Of-Presence (SOP), Cybersickness, Performance, And Levels Of Excitement In Virtual Environments, Telematic Environment, And Real Environments Showing Similar Visual And Audio Content.

8.1 Introduction

The main contribution of Experiment 1 and Experiment 2 was the development of an assessment tool on measuring sense-of-presence (SOP). This assessment tool was presenting the Presence Questionnaire (PQ) in Cooper-Harper style and it could be used in both real and virtual environments. The benefits of using the PQ presented in Cooper-Harper were verified in Experiment 2. With the success of adapting the Cooper Harper question presenting style on PQ, this question presentation format was also adapted to the Slater's Questionnaires (Appendix 2.2b) and resulted in the Slater's Questionnaire presented using Cooper-Harper technique (Cooper-Harper rating Slater's Questionnaire, CHRSQ). The details of the CHRSQ were listed in Appendix 2.2c. Although most of the questions have already explained clearly in the PQ presented in Cooper-Harper style used in Experiment 2, there were still few wordings needed further explanations, and also question style needed to be changed. After

these changes, a new version of PQ presented in Cooper-Harper style was produced and it was called as Cooper-Harper rating Presence Questionnaire version II, CHRPQ II. Both of these SOP measurement tools were used in this experiment to explore the level of SOP that the participants experienced from virtual to real environments. In addition, the relationship among SOP, cybersickness and excitement were also studied.

8.2. Objectives

The objective of this experiment was to study the relationships among sense-of-presence (SOP), cybersickness, performance, and levels of excitement in 12 experimental environments which ranged from virtual environments to real environments showing similar visual and audio content.

8.3. Variables and apparatus

Details of the apparatus used in this experiment were listed Section 4.4.3.

8.3.1. Independent variables

The independent variables of this experiment were the sensory related variables which were acted as the building blocks of the experimental environments. These affordable sensory related variables were the image quality, field-of-view (FOV), imposed time delay, display resolution, view

mode, sense of touch and auditory. The levels of each sensory related variable that can be manipulated were listed in Table 8-1.

Table 8- 1 A summary table of the sensory related variables which were interested-in in the Experiment 3. These sensory related variables were acted as the building blocks for the experimental environments in the Experiment 3. The affordable levels of each variable were listed with descriptions.

Sensory related variables	*Levels*	*Descriptions*
Field-of-view (FOV)	3 (in degrees)	140 (H) x 90 (V) 48 (H) x 36 (V) 24 (H) x 18 (V)
Image quality	3	Real image Camera captured image Computer graphics
Imposed time delay	3 (in ms)	0 ~110 ~210
Display resolution	3 (in pixels)	8400 (H) x 5400 (V) 640 (H) x 480 (V) 475 (H) x 115 (V)
View mode	2	Binocular Biocular (i.e. both eyes seeing the same image)
Sense of touch	2	Real sense of touch Visual and audio cues without the physical sense of touch
Auditory	2	3-dimensional (3D) 1-dimensional (1D)

8.3.2. Dependent variables

The four measurements of this experiment were the subjective level of sense-of-presence (SOP) of the participants, their levels of cybersickness and excitement, and the task performance. The details of the dependent variables were listed in Section 4.2.3.

8.4. Procedure and design of experiment

The range of the selected sensory related variables covered from real to virtual was listed in Table 8-1. If we used all of the combinations of these sensory related variables to form environments, there would be 648 environments needed to be constructed![*] In addition, if there were 10 participants assigned to each environment, there would be totally 6480 conditions needed to be run for this experiment. However due to the limitation of resources and time, this design was impossible to be achieved. Furthermore, some of the combinations were impossible to be used to form the environments. For example, participants could not experience a real environment without physical touch, and participants did not experience the time delay on images in virtual environment. Therefore the orthogonal array (OA) design was adapted to reduce the number of runs but at the same time the interested main effects and interactions effects could be studied.

8.4.1. Orthogonal Array (OA) design

There were 7 sensory related variables to be manipulated which were image quality, field-of-view (FOV), imposed image lag, view mode, display resolution, sense of touch and auditory (Table 8-1). Only 5 of these 7 sensory interface variables were selected to be included in the OA design to build the virtual environments. The selected five sensory interface variables were FOV imposed time delay, view mode, display resolution and auditory. From these 5 sensory related variables, only 2 levels were selected from each of them to form the virtual environments. Details of these 5 selected sensory interface variables were as followed: field-of- view (FOV in degrees): 2 levels (48 x 36, 24 x 18); view mode: 2 levels (binocular, biocular); imposed time delay: 2 levels (120ms , 210ms), auditory: 2 levels (3D sound, 2D sound) and display resolution (in pixel): 2 levels (475 x 115, 640 x 480). However up to this design stage, full factorial was still unaffordable. If using the full factorial design, there would be 2^5=32 virtual environments needed to be constructed which was still time-consuming and expensive. On the other hand, by using the $L_8(2^7)$ OA design with these 5 sensory interface variables, only 8 virtual environments were needed to be constructed and at the same time the main effects and the interested interaction effects of the selected sensory related variables could be studied (see Table 8-2). By using the

$L_8(2^7)$ OA design, main effects of FOV, imposed time delay, view mode, auditory and display resolution were found so as the interaction effects of FOV*imposed time delay and FOV*view mode.

There were another 3 experimental environments which were constructed:

X1) Telematic Environment (TE): FOV (in degrees): 48 x 36, imposed time delay: 110ms, view mode: binocular, display resolution (in pixels): 640 x 480, auditory: 3D sound and real sense of touch

X2) RE_restricted: FOV (in degrees): 48x36, imposed time delay: 0ms, view mode: binocular, display resolution in pixel: 8400 x 5400, auditory: 3D sound and real sense of touch

X3) RE: FOV (in degrees): 140 x 90 (normal human vision's FOV), imposed time delay: 0ms, view mode: binocular, display resolution: 8400 x 5400, auditory: 3D sound and real sense of touch

X4) VE_best: FOV (in degrees): 48x36, imposed time delay: 0ms but with basic 100ms time delay, view mode: binocular, display resolution (in pixel) : 640 x 480, sense of touch: visual and audio cues and without the physical sense of touch, auditory: 3D sound

Table 8- 2 The OA design with 5 selected sensory interface variables in order to form 8 virtual environments which were used in Experiment 3. The five sensory variables were field-of-view (FOV), view mode, imposed time delay, auditory and tactile sensation. FOV (in degrees): (1) 48 x 36, (2) 24 x 18, View:(1) binocular, (2) biocular; imposed time delay: (1) 110ms , (2) 210ms; Auditory: (1) 3D sound, (2) 2D sound; display resolution in pixels: (1) 640 x 480 , (2) 475 x 115).

	Sensory related variables						
Experimental environments	***FOV***	***Imposed time delay***	***FOV* Imposed time delay***	***View***	***FOV*View***	***Auditory***	***Display resolution***
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

8.4.2. Participants and Procedure

There were 10 participants (5 males, 5 females) assigned to each environment. All of the participants were university students and staff. Before the experiment started, participants were asked to fill in the Immersive Tendency Questionnaire (ITQ), Pre-Simulator Sickness Questionnaire (Pre-SSQ). During the experiment, participants completed the eyesight test task, visual search task, moving cylinder task, sound localisation task, distance estimation task and navigation task. After the experiment finished, participants filled in the Post-SSQ, Cooper-Harper rating Slater's Questionnaire (CHRSQ), the second version of Cooper-Harper rating Presence Questionnaire (CHRPQ II), the Excitement Questionnaire and

perspective drawing. The order of CHRSQ and CHRPQ II was randomized to eliminate any order effect.

8.5. Hypotheses

There were 5 hypotheses on the effects of the sensory related variables on the subjective level of SOP. These hypotheses were mostly based on the past studies (see Section 3.1). They were listed as below:

H3-1a: Field-of-view (FOV) would have significant effect on the subjective level of SOP. With the larger FOV, the participants experienced higher level of SOP.

H3-1b: Imposed time delay would have significant effect on the subjective level of SOP. With long imposed time delay, participants experienced lower level of SOP.

H3-1c: View mode would have significant effect on the subjective level of SOP. Participants viewed the environments in binocular view experienced higher level of SOP than in biocular view.

H3-1d: Display resolution would have significant effect on the subjective level of SOP. Level of SOP increased with the level of display resolution.

H3-1e: Auditory would have significant effect on the subjective level of SOP. Participants listened to the 3D sound felt higher level of SOP than listened to the 1D sound.

Hypotheses on the effects of the sensory related variables on the moving cylinder task completion time were as followed:

H3-2a: Imposed time delay would have significant effect on the moving cylinder task completion time. The moving cylinder completion time would be longer with long imposed time delay.

H3-2b: View mode would have significant effect on the moving cylinder task completion time. Binocular view would affect the participants' perception of distance/depth and the participants needed longer time to finish the moving cylinder task.

Hypotheses on the effects of sensory variables on the visual search completion time:

H3-3a: display resolution would have significant effect on the visual search task completion time. With poor display resolution, participants would take longer time to recognise the target objects and hence the visual search completion time would be longer.

H3-3b: FOV would have significant effect on the visual search task completion time. Smaller FOV required participants to use more time on finding all the target objects.

H3-3c: Imposed time delay would have significant effect on the visual search task completion time. Longer time delay required participants to spend more time to complete the visual search task.

H3-4: Gender would have significant effect on both the SSQ score (Kolasinski, 1995) and performance (Boff, et al., 1988).

H3-5: SOP would be positively correlated with task performance (Barfield, et al., 1993). When the level of SOP was high which would cause the participants to allocate more of their attentions towards the tasks, as a result the task performance would be high.

H3-6a: The time for completing the moving cylinder task would be shorten with the presence of natural sense of touch, instead of using the visual and audio cues only.

H3-6b: Sense of touch would have no significant effect on SSQ score.

H3-6c: Sense of touch would have significant effect on the haptic subscale score and the total score of the CHRPQ II.

H3-7: Correlation between excitement level and SOP was expected.

H3-8: Correlation between CHRPQ II and CHRSQ was expected as both of them measured SOP.

8.6. Results

8.6.1. Sense-of-presence (SOP) measured by the Presence Questionnaire (PQ) scores (PQ presented in Cooper-Harper rating style)

Figure 8-1 shows the variation of SOP of the male participants measured by CHRPQ II along with the 12 experimental environments. Observation from this figure (Figure 8-1) shows that the male participants at real environments (i.e. the RE_restricted (x3) and the RE (x4)) experienced the highest level of SOP. Male participants at the TE(x1) experienced less SOP than in VE_best and also similar to the other virtual environments (1-8). Figure 8-2 shows the SOP, measured by CHRPQ II, of the female participants among the 12 experimental environments. The pattern of PQ score variation is similar to the male participants (Figure 8-2). Figure 8-3 shows the combinations of female and male participants' scores of PQ subscales and total scores with standard deviations. In this figure, the level of SOP were also highest in the real environments (x2 and x3) and this was due to that both male and female participants in these environments experienced the highest level of SOP as observed from Figures 8-1 and 8-2.

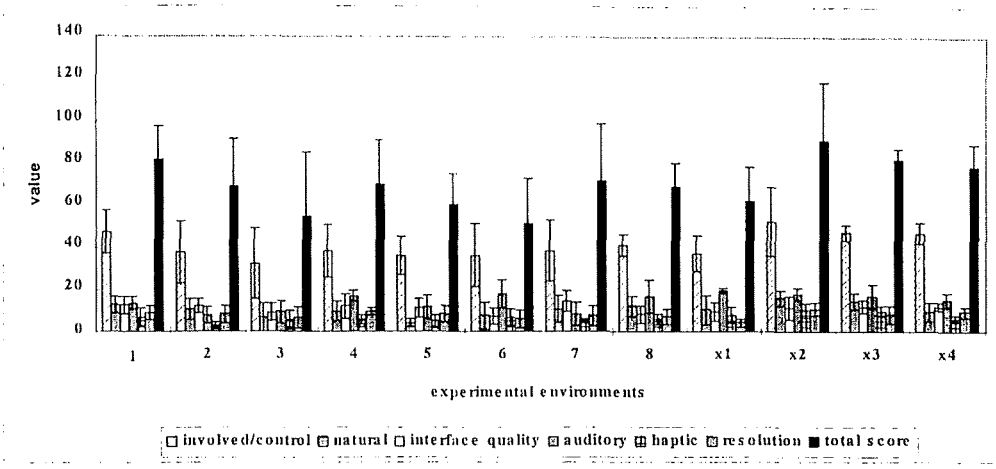

Figure 8- 1 The average PQ (represented in Cooper-Harper rating, CHRPQ II) subscales and the total scores of the male participants from the 12 experimental environments which ranged from virtual to real in Experiment 5 (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best). The subscales are involved/control, natural, interface quality, auditory, haptic and resolution. The bars denoted ± 1 standard deviations.

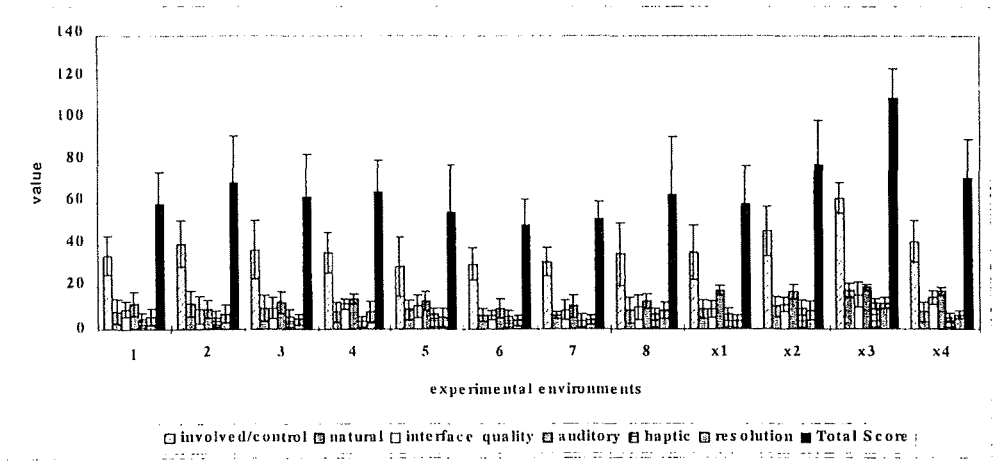

Figure 8-2 The average PQ (represented in Cooper-Harper rating, CHRPQ II) subscales and the total scores of the female participants from the 12 experimental environments which ranged from virtual to real in Experiment 5 (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best). The subscales are involved/control, natural, interface quality, auditory, haptic and resolution. The bars denoted ± 1 standard deviations

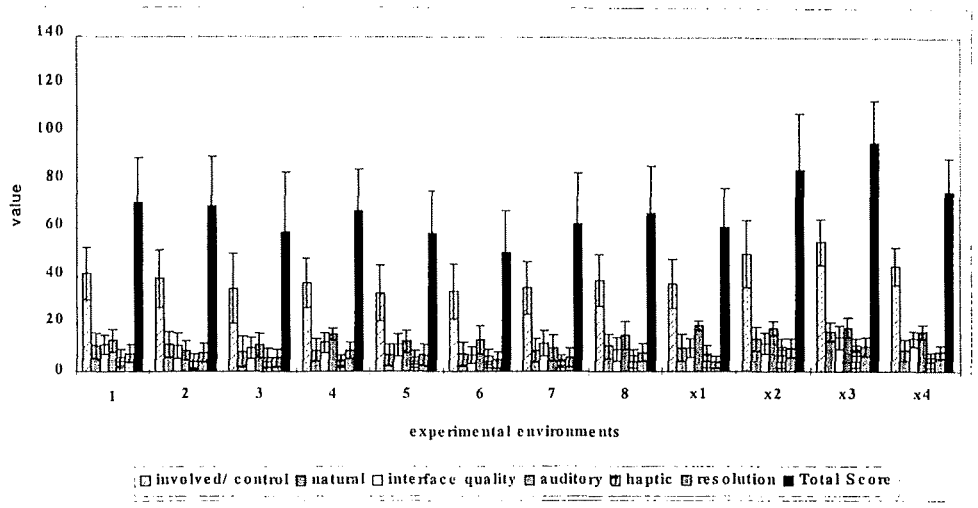

Figure 8-3 The average PQ (represented in Cooper-Harper rating, CHRPQ II) subscales and the total scores of the male and female participants from the 12 experimental environments which ranged from virtual to real in Experiment 5. The subscales are involved/control, natural, interface quality, auditory, haptic and resolution. The 12 experimental environments coding : 1-8 were the OA designed virtual environments, x1: TE, x2: RE_restricted, x3: RE and x4: VE_best. The bars denoted ± 1 standard deviations.

Tables 8-3 to 8-4 show the mean value and the standard deviations of the CHRPQ II subscales and total scores of both the male and female participants in the 12 experimental environments of the Experiment 5. Table 8-5 shows the median value of the PQ subscales and the total score of the participants in the 12 experimental environments.

Table 8- 3 The average PQ (presented in Cooper-Harper style, CHRPQ II) subscales and the total scores of the male and female participants from the 12 experimental environments which ranged from virtual to real in Experiment 5 (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best). The subscales are involved/control, natural, interface quality, auditory, haptic and resolution.

Experimental environment	*gender*	*Involved/ control*	*Natural*	*Interface quality*	*Auditory*	*Haptic*	*Resolution*	*Total score*
1	M	47.40	13.00	12.80	13.80	7.00	8.80	82.00
	F	35.00	8.60	9.80	12.40	5.00	6.20	59.60
	overall	41.20	10.80	11.30	13.10	6.00	7.50	70.80
2	M	37.80	10.60	12.40	8.00	2.80	8.20	69.00
	F	40.60	12.20	9.40	9.60	5.60	7.40	69.60
	overall	39.20	11.40	10.90	8.80	4.20	7.80	69.30
3	M	32.40	6.60	9.20	9.40	5.60	6.60	54.80
	F	37.80	10.20	10.20	13.00	6.00	4.80	63.00
	overall	35.10	8.40	9.70	11.20	5.80	5.70	58.90
4	M	38.40	9.80	12.20	17.20	5.60	9.40	69.80
	F	36.40	8.20	12.20	14.60	3.80	8.40	65.20
	overall	37.40	9.00	12.20	15.90	4.70	8.90	67.50
5	M	36.20	4.20	11.40	11.80	4.80	8.40	60.20
	F	29.80	9.40	11.00	13.40	7.40	5.60	55.80
	overall	33.00	6.80	11.20	12.60	6.10	7.00	58.00
6	M	36.40	7.67	7.33	18.00	6.67	6.00	51.33
	F	31.20	7.00	6.80	10.20	6.00	4.40	49.40
	overall	33.80	7.25	7.00	13.13	6.25	5.00	50.13
7	M	38.60	11.00	14.40	8.40	5.20	7.80	71.80
	F	32.00	6.80	9.20	11.00	4.20	4.40	52.40
	overall	35.30	8.90	11.80	9.70	4.70	6.10	62.10
8	M	41.00	12.20	8.20	16.80	6.00	7.20	68.60
	F	35.80	9.00	10.60	13.60	7.40	8.80	64.20
	overall	38.40	10.60	9.40	15.20	6.70	8.00	66.40
x1	M	37.20	10.60	9.80	19.80	8.00	4.40	62.00
	F	36.60	9.60	9.60	18.40	7.20	3.80	59.60
	overall	36.90	10.10	9.70	19.10	7.60	4.10	60.80
x2	M	52.40	16.20	11.40	18.00	10.20	10.80	90.80
	F	46.60	11.00	11.80	18.20	10.40	9.00	78.40
	overall	49.50	13.60	11.60	18.10	10.30	9.90	84.60
x3	M	47.20	14.60	12.00	16.80	9.80	8.20	82.00
	F	62.20	18.80	16.40	20.00	12.20	12.60	110.00
	overall	54.70	16.70	14.20	18.40	11.00	10.40	96.00
x4	M	47.00	9.80	12.00	15.00	6.20	9.40	78.20
	F	41.80	8.20	15.20	18.40	5.60	7.00	72.20
	overall	44.40	9.00	13.60	16.70	5.90	8.20	75.20

Table 8- 4 The standard deviations of PQ (represented in Cooper-Harper rating, CHRPQ II) subscales and the total scores of the male and female participants from the 12 experimental environments which ranged from virtual to real in Experiment 5 (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best) . The subscales are involved/control, natural, interface quality, auditory, haptic and resolution

Experimental environments	*gender*	*Involved/ control*	*Natural*	*Interface quality*	*Auditory*	*Haptic*	*Resolution*	*Total Score*
1	M	10.09	3.74	4.32	3.35	4.12	3.35	47.40
	F	9.19	6.07	3.63	5.86	2.83	3.77	35.00
	overall	11.20	5.29	4.08	4.56	3.50	3.63	41.20
2	M	14.45	5.22	3.65	3.94	1.79	4.32	37.80
	F	10.99	6.14	6.58	4.22	3.51	4.22	40.60
	overall	12.19	5.44	5.26	3.94	3.01	4.05	39.20
3	M	16.64	6.99	4.32	5.18	4.62	5.13	32.40
	F	13.88	6.22	5.07	5.15	3.39	2.28	37.80
	overall	14.72	6.52	4.47	5.22	3.82	3.86	35.10
4	M	12.44	4.97	5.81	2.39	2.19	1.67	38.40
	F	9.48	4.87	2.39	2.07	2.49	5.13	36.40
	overall	10.48	4.71	4.18	2.51	2.41	3.63	37.40
5	M	9.04	1.79	4.39	5.50	3.03	4.04	36.20
	F	14.27	4.72	5.39	4.56	2.61	4.51	29.80
	overall	11.76	4.34	4.64	4.84	3.00	4.29	33.00
6	M	14.98	6.38	4.16	6.98	3.83	4.15	36.40
	F	7.33	3.08	2.39	4.60	2.92	2.61	31.20
	overall	11.45	4.86	3.48	5.89	3.24	3.35	33.80
7	M	14.57	6.44	5.08	5.68	1.10	4.71	38.60
	F	6.63	1.64	4.82	5.48	3.03	2.30	32.00
	overall	11.23	4.95	5.41	5.44	2.21	3.93	35.30
8	M	5.15	4.66	4.32	7.76	2.35	3.56	41.00
	F	14.79	6.12	5.94	3.44	2.97	3.90	35.80
	overall	10.79	5.40	5.06	5.90	2.63	3.62	38.40
x1	M	8.29	6.95	4.55	1.30	4.06	2.07	37.20
	F	12.99	4.67	3.78	2.19	3.03	3.03	36.60
	overall	10.28	5.61	3.95	1.85	3.41	2.47	36.90
x2	M	16.47	3.70	5.59	2.92	3.42	3.11	52.40
	F	11.82	4.90	3.56	3.35	3.65	4.53	46.60
	overall	13.86	4.93	4.43	2.96	3.33	3.78	49.50
x3	M	3.70	3.85	3.08	5.67	2.68	4.38	47.20
	F	7.36	3.35	5.81	1.22	2.49	2.61	62.20
	overall	9.63	4.06	4.96	4.22	2.75	4.12	54.70
x4	M	4.85	4.44	2.00	3.39	1.79	2.61	47.00
	F	10.01	4.82	3.27	1.82	2.30	2.12	41.80
	overall	7.90	4.45	3.06	3.13	1.97	2.57	44.40

Table 8- 5 The median of PQ (represented in Cooper-Harper rating, CHRPQ II) subscales and the total scores of the male and female participants from the 12 experimental environments which ranged from virtual to real in Experiment 5 (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best). The subscales are involved/control, natural, interface quality, auditory, haptic and resolution

Experimental environments	*gender*	*Involved/ control*	*Natural*	*Interface quality*	*Auditory*	*Haptic*	*Resolution*	*Total Score*
1	M	49.00	12.00	13.00	13.00	7.00	8.00	85.00
	F	32.00	7.00	8.00	14.00	6.00	6.00	61.00
	overall	38.50	12.00	11.50	13.50	6.50	6.50	68.50
2	M	43.00	10.00	11.00	6.00	2.00	9.00	75.00
	F	39.00	13.00	12.00	11.00	4.00	9.00	74.00
	overall	41.00	11.50	11.50	9.00	3.00	9.00	74.50
3	M	28.00	3.00	9.00	11.00	4.00	5.00	43.00
	F	35.00	13.00	9.00	14.00	6.00	4.00	63.00
	overall	31.00	4.50	9.00	12.50	5.00	4.50	50.50
4	M	38.00	9.00	14.00	18.00	6.00	9.00	83.00
	F	41.00	9.00	13.00	15.00	3.00	10.00	67.00
	overall	39.50	9.00	13.00	16.50	5.00	9.50	71.50
5	M	37.00	3.00	11.00	11.00	3.00	9.00	65.00
	F	26.00	8.00	12.00	13.00	7.00	3.00	55.00
	overall	34.50	6.00	11.50	12.00	6.50	7.00	60.00
6	M	45.00	7.00	11.00	13.00	4.00	4.00	74.00
	F	34.00	7.00	8.00	11.00	5.00	4.00	51.00
	overall	35.00	7.00	8.00	11.00	4.50	4.00	56.00
7	M	37.00	15.00	16.00	8.00	6.00	6.00	67.00
	F	31.00	7.00	8.00	11.00	2.00	5.00	55.00
	overall	31.50	7.50	10.50	10.00	5.00	6.00	59.50
8	M	41.00	11.00	9.00	20.00	5.00	7.00	66.00
	F	34.00	7.00	12.00	15.00	8.00	10.00	69.00
	overall	39.00	10.00	9.00	16.00	7.00	8.50	66.00
x1	M	32.00	15.00	8.00	20.00	8.00	4.00	58.00
	F	33.00	11.00	8.00	19.00	6.00	2.00	54.00
	overall	32.50	11.50	8.00	19.00	7.00	3.50	58.00
X2	M	57.00	16.00	12.00	19.00	11.00	10.00	95.00
	F	48.00	13.00	11.00	19.00	12.00	11.00	84.00
	overall	50.00	14.00	11.50	19.00	11.50	10.50	85.00
X3	M	48.00	16.00	12.00	19.00	10.00	8.00	82.00
	F	59.00	20.00	19.00	20.00	13.00	14.00	111.00
	overall	52.50	17.00	15.00	20.00	11.00	11.50	91.50
x4	M	49.00	10.00	13.00	13.00	6.00	9.00	84.00
	F	45.00	11.00	16.00	18.00	6.00	7.00	81.00
	overall	45.50	10.50	13.50	17.50	6.00	8.00	82.50

8.6.2. Sense-of-presence (SOP) measured by the Slater's Questionnaire scores (Slater's Questionnaire presented in Cooper-Harper rating style, CHRSQ)

Figure 8-4 shows the average score value of the total 6 Cooper-Harper formatted Slater's questionnaire's (CHRSQ) responses from the participants across the 12 experimental environments. Observations of the average score of each of the question in the CHRSQ, there were no differences among the experimental environments, however large variations among the ratings were observable. Table 8-6 shows the mean and standard deviations of the CHRSQ ratings among the 12 experimental environments and it further confirmed the large variations of the ratings occurred between the participants.

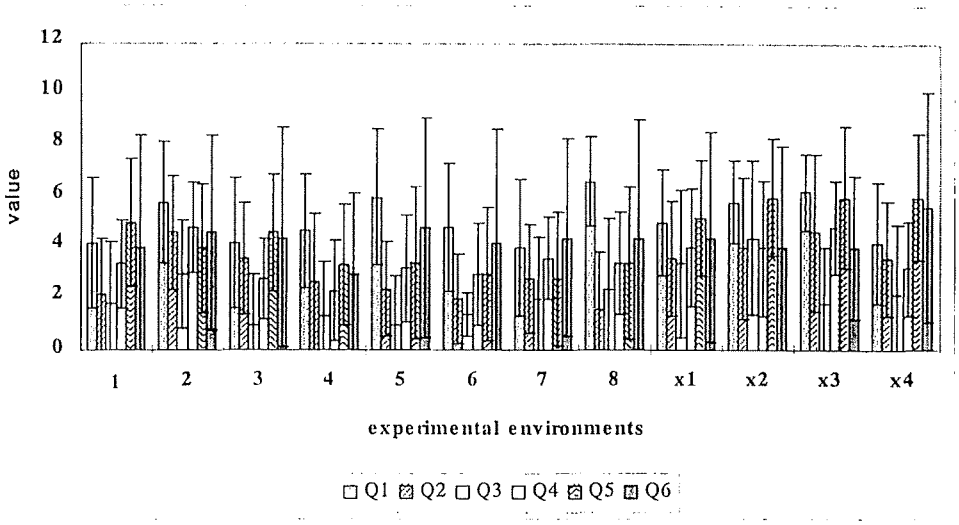

Figure 8- 4 The mean rating of each question from the Cooper-Harper rating Slater's Questionnaire (CHRSQ) from the participants (female+male) among the 12 experimental environments (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best). The bars denoted ±1 standard deviation

Table 8- 6 The mean and standard deviations of each question response and the total score from CHRSQ among the 12 experimental environments (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best) in Experiment 5.

	mean							Standard deviations						
Experimental environment	Q1	Q2	Q3	Q4	Q5	Q6	TOTAL	Q1	Q2	Q3	Q4	Q5	Q6	TOTAL
1	4.7	2.5	2.5	4.1	3.5	4.4	1.8	2.54	2.17	2.46	1.73	2.51	2.50	1.48
2	5.6	3.8	2.1	4.7	3.9	3.8	2.4	**2.37**	**2.20**	**2.13**	**1.77**	**2.51**	**2.44**	**1.30**
3	5.1	3.4	2	2.7	4.8	4.3	1.9	2.56	2.17	2.00	1.57	2.30	2.11	1.20
4	5.17	2.83	1.83	3.50	4.00	3.17	2.30	2.22	2.72	2.13	1.97	2.38	2.16	1.57
5	4.50	2.50	1.60	4.20	3.80	4.30	2.00	2.68	1.84	1.90	2.10	2.97	2.50	1.33
6	5.43	2.43	1.57	3.86	4.00	4.43	2.00	2.49	1.78	0.85	2.01	2.62	2.46	1.15
7	3.88	3.25	2.88	3.13	2.88	3.88	1.90	2.68	2.13	2.44	1.62	2.62	2.55	0.99
8	5.90	2.70	3.70	3.70	3.80	4.60	2.40	1.73	2.26	2.75	2.00	2.97	1.51	0.97
X1	5.50	4.60	3.20	3.50	5.20	4.10	2.80	2.07	2.27	2.90	2.32	2.25	1.85	1.23
X2	6.20	3.90	4.50	3.80	5.00	4.00	2.90	1.62	2.77	3.03	2.66	2.26	1.89	1.60
X3	**6.30**	**3.90**	**2.30**	**5.30**	**4.30**	**2.80**	**2.50**	1.49	3.07	2.21	1.83	2.75	1.81	1.08
X4	4.80	3.40	3.00	3.50	4.70	4.50	2.10	2.39	2.27	2.71	1.84	2.45	2.17	1.79

The total score of the Cooper-Harper format Slater's Questionnaire also represented the level of the SOP that the participants experienced in the experimental environments. The total score was calculated from the instructions of Dr. Slater's past studies (Appendix 2.2a). The calculation

method is if the rating of a question is larger than 5, then that question will count as score of 1. Therefore the highest SOP total score of the CHRSQ was 6 (ie. Each question rating is larger than 5 = 6 questions x 1 score). Figure 8-5 shows the mean value of the CHRSQ total score and Figure 8-6 shows the median value of the CHRSQ total score.

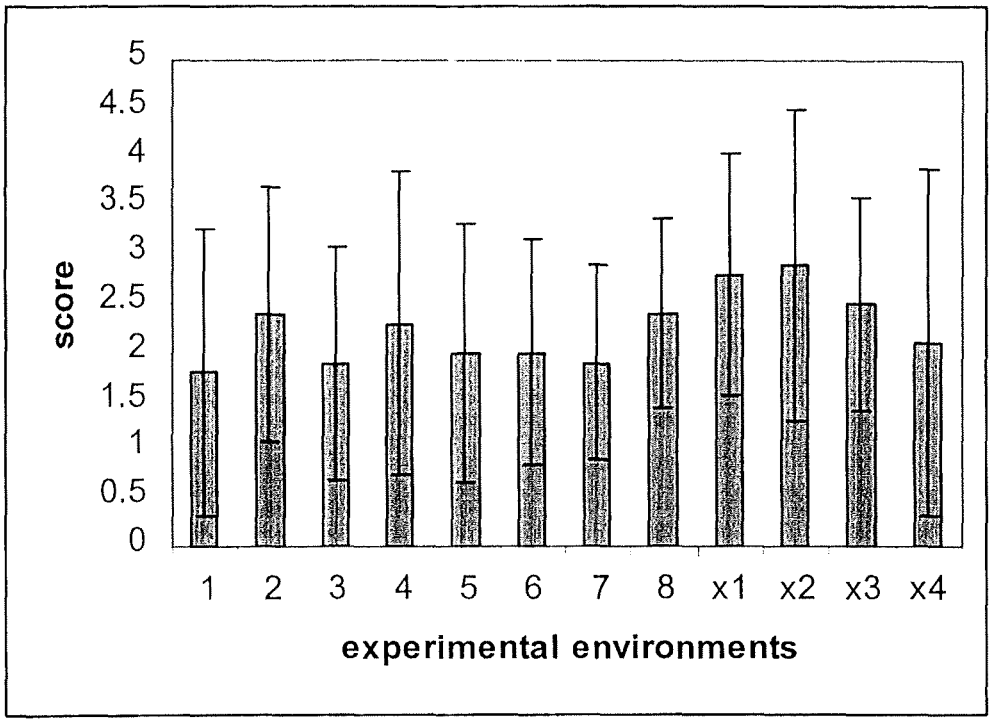

Figure 8- 5 The mean value of the Slater's Questionnaire presented in Cooper-Harper style (CHRSQ) total score from the participants among the 12 experimental environments (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best) in Experiment 5. The bars denoted ±1 standard deviation

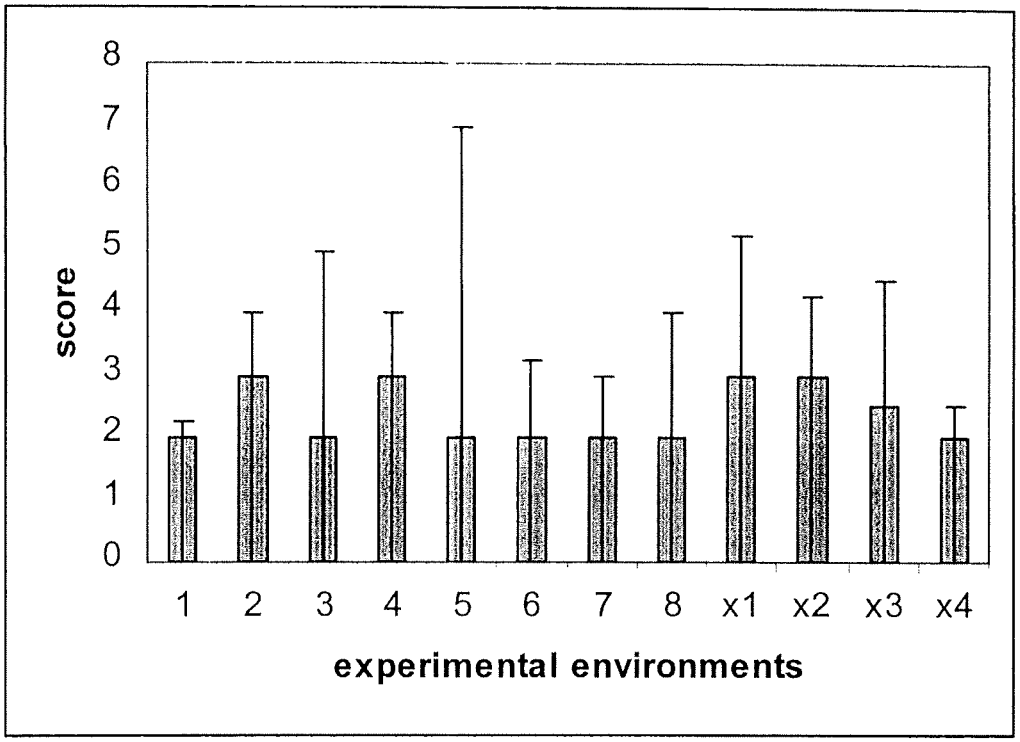

Figure 8- 6 The median values of the total score among the 12 experimental environments (8 OA virtual environments, x1: TE, x2: RE_restricted, x3: RE and x4: VE_best) in Experiment 5. Bars denoted the ±1 quartile.

8.6.3. The Simulator Sickness Questionnaire (SSQ) score

SSQ contains 3 subscores and a total score which reflects the overall level of cybersickness that the participants experienced during the experiment. The 3 subscores are nausea, oculomotor and disorientation and the details of the calculation were described in Section 3.2. Figures 8-7 to 8-9 report the mean value of the (Post-Pre) SSQ subscales that the participants experienced during the experiment. Observations from these figures show that participants in the real environments (ie RE and RE_restricted) experienced

the least amount of nausea, oculomotor and disorientation during the experiment. In addition, the participants in the TE suffered the discomfort caused by disorientation most. However there were no observable differences between TE and VE on the level of disorientation that the participants suffered during the experiment.

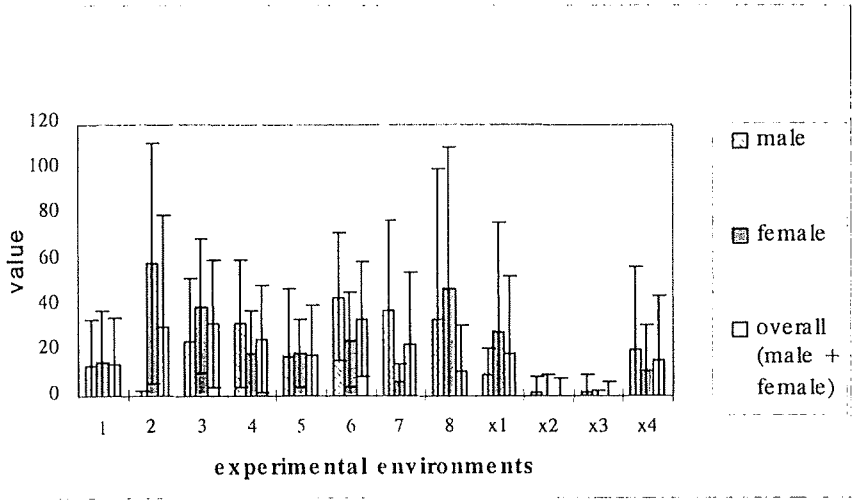

Figure 8- 7 The average nausea rating measured by Simulator Sickness Questionnaire (SSQ) among the 12 experiments (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best) in Experiment 5. Bars denoted ±1 standard deviation.

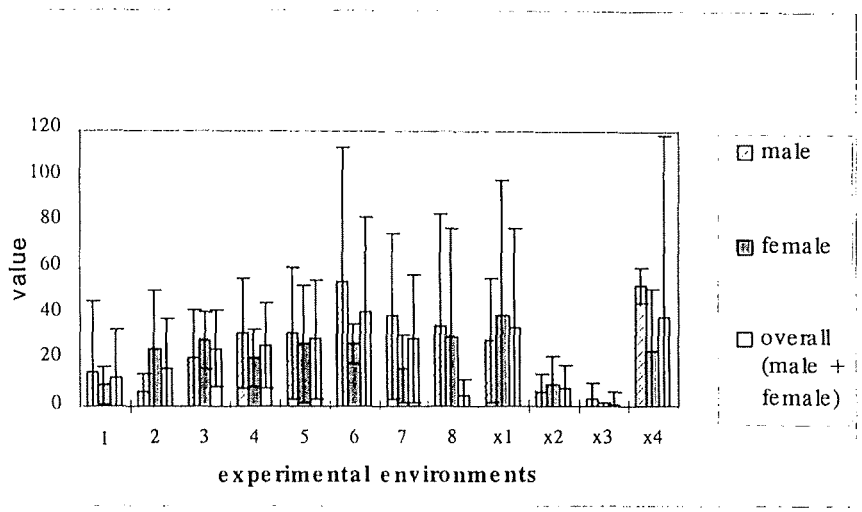

Figure 8- 8 The average oculomotor rating measured by Simulator Sickness Questionnaire (SSQ) among the 12 experiments (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best) in Experiment 5. Bars denoted ±1 standard deviation.

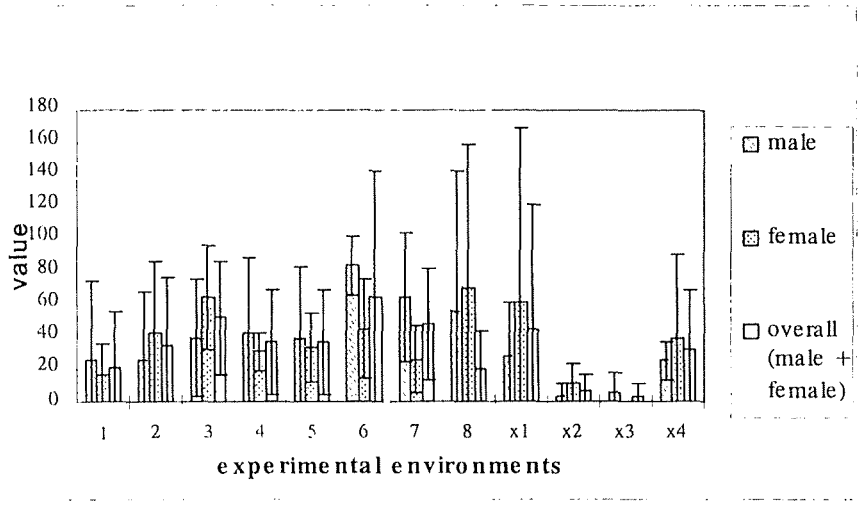

Figure 8- 9 The average disorientation rating measured by Simulator Sickness Questionnaire (SSQ) among the 12 experiments (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best) in Experiment 5. Bars denoted ±1 standard deviation.

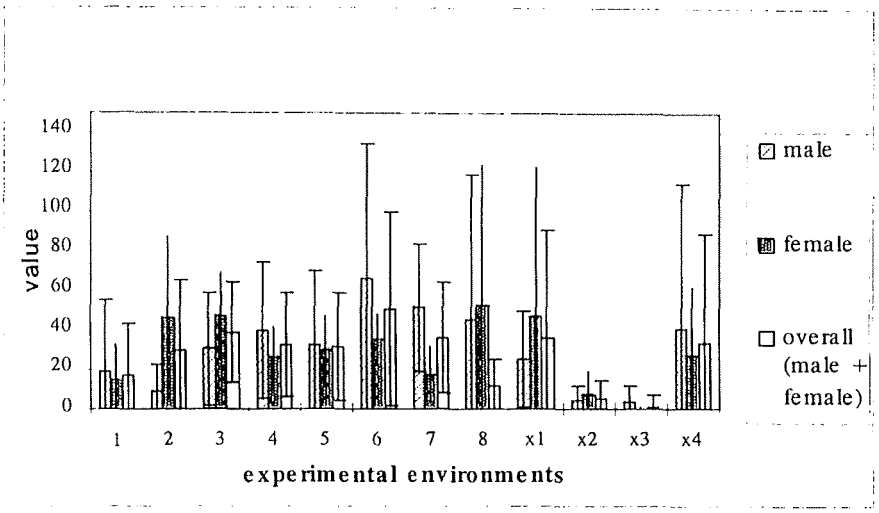

Figure 8- 10 The average Total sickness rating (total score) measured by Simulator Sickness Questionnaire (SSQ) among the 12 experiments (1-8: 8 OA experimental environments, x1: TE, x2: RE_restricted, x3: RE, x4: VE_best) in Experiment 5. Bars denoted ±1 standard deviation.

Figure 8-10 shows the overall level of cybersickness that the participants experienced in the Experiment 5, it shows that participants in real environments reported least amount of cybersickness. Furthermore, participants in the TE experienced similar level of cybersickness as in the virtual environments.

Above listed figures shows that the variations of cybersickness were large and hence hard to do comparisons, therefore below figure (Figure 8-11) reports the median value of SSQ scores reported from both the male and female participants in Experiment 5. It also shows that the participants in the real environments experienced least amount of cybersickness during the experiment, and TE and VE provided similar amount of cybersickness to the participants which were similar to the observation from mean total score shown in Figure 8-10.

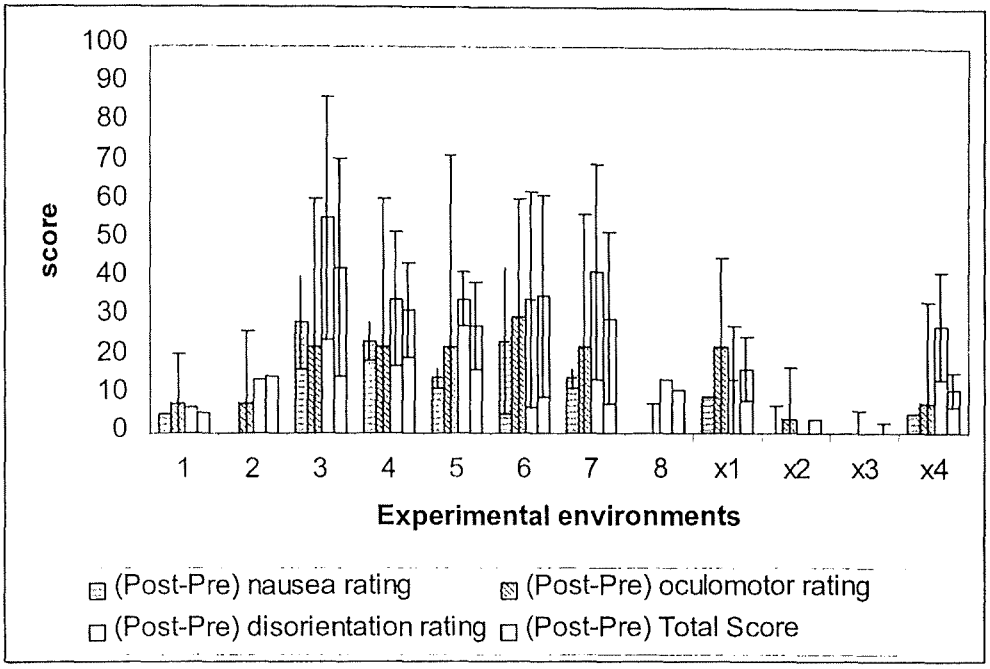

Figure 8- 11 The median value of the reported Simulator Sickness Questionnaire subscores and total score among the 12 experimental environments in Experiment 5. The subscores are nausea, oculomotor and disorientation. The 12 experimental environments were the 8 virtual environments designed by the OA (1-8), TE(x1), RE-restricted (x2), RE (x3) and VE_best (x4). The data are from both male and female participants. The bars denoted ± 1 quartile.

8.6.4. The task performance

There were 2 measurements on task performance; these 2 measurements were visual search task completion time and moving cylinder task completion time.

The bar graph of the average visual search time is plotted as below (Figure 7-12). As seen from the graph, participants in the real environments were high compared with the other experimental environments in Experiment 5. Another piece of information could be obtained from this graph was that the participants spent similar amount of time to finish the visual search task throughout the 12 experimental environments in this experiment, and this was also shown in Table 7-8.

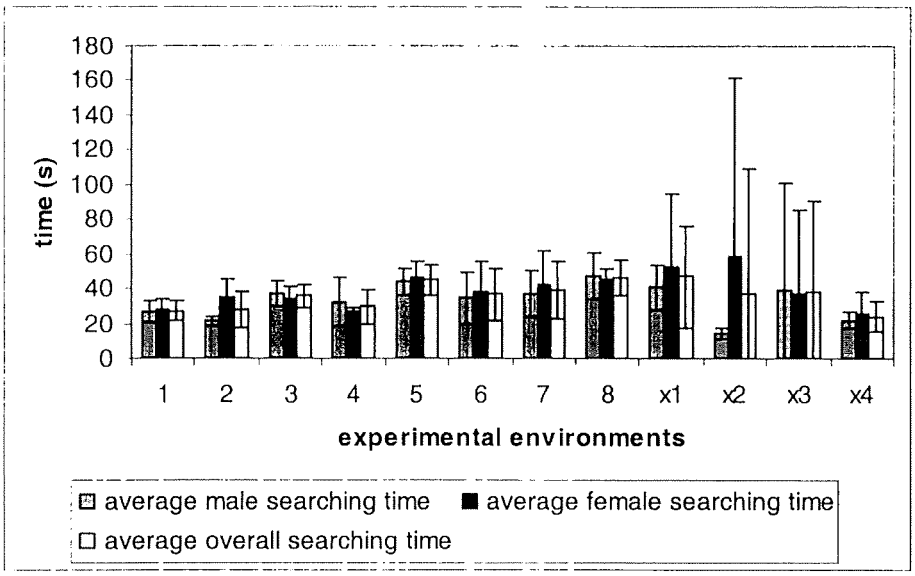

Figure 8- 12 The average visual search task completion time in second among the 12 experimental environments in Experiment 5. The 12 experimental environments were the 8 virtual environments designed by the OA (1-8), TE(x1), RE-restricted (x2), RE (x3) and VE_best (x4).Bars denoted ±1 standard deviation.

Table 8- 7 The descriptive statistics of the visual search task completion time among the 12 experimental environments in Experiment 5. The 12 experimental environments were the 8 virtual environments designed by the OA (1-8), TE(x1), RE-restricted (x2), RE (x3) and VE_best (x4).

Experimental environments	Gender	Average visual search completion time (S)	SD of the visual search completion time (s)	Median visual search completion time (s)	1st quartile of the visual search completion time (s)	3rd quartile of the visual search completion time (s)
1	M	26.61	5.95	28.90	27.86	29.40
	F	27.89	5.63	25.60	24.02	32.51
	overall	27.25	5.50	28.38	24.41	30.41
2	M	21.16	2.91	20.69	19.74	22.11
	F	35.02	10.69	34.45	34.45	34.45
	overall	27.83	10.56	23.39	23.39	23.39
3	M	37.16	6.92	38.69	30.14	41.12
	F	34.02	7.47	36.24	32.94	38.44
	overall	35.59	6.99	37.34	30.84	40.27
4	M	32.04	13.73	32.68	19.19	37.26
	F	27.06	2.02	26.07	25.83	27.64
	overall	29.55	9.62	26.86	25.51	32.10
5	M	43.72	7.93	43.56	38.29	48.35
	F	45.87	9.89	41.27	38.44	52.20
	overall	44.80	8.53	42.41	38.33	51.24
6	M	34.55	14.88	26.94	25.40	38.22
	F	38.56	16.82	31.78	31.57	37.84
	overall	36.56	15.12	31.68	25.79	38.13
7	M	36.91	13.73	31.48	30.52	36.77
	F	41.68	20.07	37.01	29.23	41.46
	overall	39.30	16.40	34.12	29.55	40.35
8	M	47.13	13.69	50.10	44.41	51.40
	F	45.04	6.31	44.70	42.59	50.23
	overall	46.09	10.11	47.40	43.05	51.11
x1	M	40.77	12.75	36.98	30.32	52.44
	F	52.86	41.45	44.70	39.60	44.70
	overall	46.82	29.60	42.15	31.98	50.50
X2	M	14.63	3.26	13.64	13.11	15.85
	F	58.46	102.80	13.24	6.57	25.26
	overall	36.55	72.36	13.44	11.52	18.65
X3	M	39.39	60.96	10.07	9.72	19.25
	F	36.55	48.97	13.95	12.62	24.43
	overall	37.97	52.15	13.29	9.81	23.14
X4	M	21.95	4.47	21.25	17.99	24.85
	F	26.03	11.52	24.43	16.89	27.70
	overall	23.99	8.51	22.84	17.73	26.99

On the moving cylinder task completion time, the changes among the experimental environments were obvious (Figure 8-13, Table 8-8). The graph (Figure 8-13) shows that participants spent the least amount of time to complete the whole moving cylinder task in the real environments (x2 and x3). The participants in TE (x1) and VE_best (x4) spent similar amount of time to finish the moving cylinder task and the time were a lot less than the

other virtual environments. Furthermore on inspecting the moving cylinder trial time along the trials (Figure 8-14), there was no typical pattern along the trial order at all

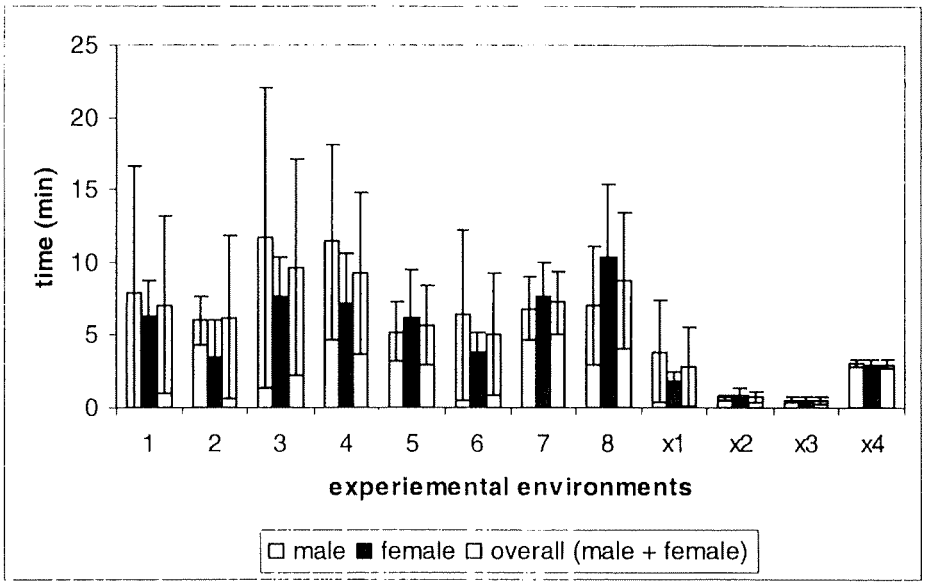

Figure 8- 13 The average moving cylinder completion time (in minute) among the 12 experimental environments in Experiment 5. The 12 experimental environments included the 8 virtual environments formed by the OA design (1 -8), TE (x1), RE_restricted (x2), RE (x3) and the VE_best (x4). Bars denoted the ± 1 standard deviations.

Table 8- 8 The descriptive statistics of the moving cylinder task completion time (min) among the 12 experimental environments from Experiment 5. The 12 experimental environments included the 8 virtual environments formed by the OA design (1 -8), TE (x1), RE_restricted (x2), RE (x3) and the VE_best (x4). Bars denoted the ± 1 standard deviations.

Experimental environments	Gender	Average moving cylinder task completion time (min)	SD of the moving cylinder task completion time (min)	Median moving cylinder task completion time (min)	1st quartile moving cylinder task completion time (min)	3rd quartile moving cylinder task completion time (min)
1	M	7.88	8.70	4.65	3.26	5.49
	F	6.25	2.50	4.69	4.49	8.87
	overall	7.06	6.09	4.67	4.20	8.03
2	M	6.02	1.65	6.56	5.71	6.87
	F	3.41	2.63	3.74	3.74	3.74
	overall	6.18	5.62	5.75	5.75	5.75
3	M	11.72	2.47	8.43	7.18	9.47
	F	7.60	2.79	7.41	7.11	8.88
	overall	9.66	7.44	7.92	7.13	9.32
4	M	11.39	6.74	7.49	7.47	7.48
	F	7.12	3.43	6.33	5.83	8.55
	overall	9.25	5.52	7.48	5.96	7.48
5	M	5.22	2.07	5.32	4.51	6.58
	F	6.10	3.43	5.81	5.07	7.83
	overall	5.66	2.71	5.56	4.65	7.31
6	M	6.36	5.83	4.82	4.54	6.62
	F	3.76	1.41	3.92	2.88	4.27
	overall	5.06	4.23	4.41	3.14	5.49
7	M	6.82	2.15	6.98	5.27	7.26
	F	7.61	2.32	7.53	5.83	8.61
	overall	7.21	2.15	7.12	5.41	8.34
8	M	7.00	4.05	8.29	7.31	9.57
	F	10.40	5.02	8.24	7.30	8.25
	overall	8.70	4.66	8.26	7.30	9.78
x1	M	3.87	3.55	2.66	1.84	3.04
	F	1.80	0.72	2.25	1.14	2.25
	overall	2.83	2.65	2.25	1.70	2.61
X2	M	0.68	0.22	0.75	0.68	0.81
	F	0.81	0.50	0.59	0.57	0.82
	overall	0.75	0.37	0.71	0.58	0.82
X3	M	0.55	0.20	0.61	0.36	0.66
	F	0.47	0.23	0.50	0.30	0.58
	overall	0.51	0.21	0.54	0.33	0.65
X4	M	3.05	0.27	3.06	2.96	3.26
	F	2.98	0.38	3.02	2.80	3.30
	overall	3.01	0.31	3.04	2.84	3.29

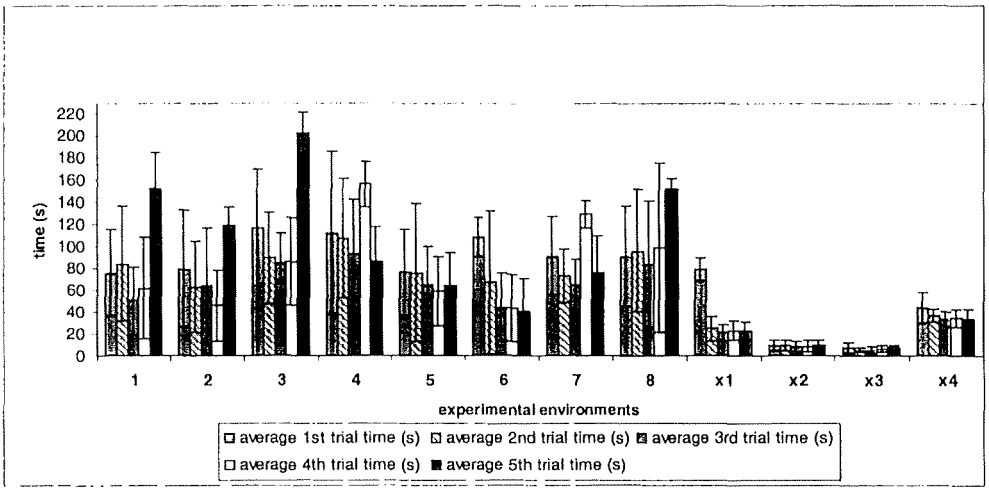

Figure 8- 14 The average moving cylinder trial time (in second) among the 12 experimental environments in Experiment 5. The 12 experimental environments included the 8 virtual environments formed by the OA design (1 -8), TE (x1), RE_restricted (x2), RE (x3) and the VE_best (x4). Bars denoted the ± 1 standard deviations.

8.6.5. The Excitement Questionnaire score

The excitement questionnaire score was divided into 3 parts which were the overall experience excitement level, the excitement level on task and navigation only and excitement level towards the experimental environment. Figure 8-15 shows that the excitement level among the virtual environments was similar. Table 8-9 also confirms this result.

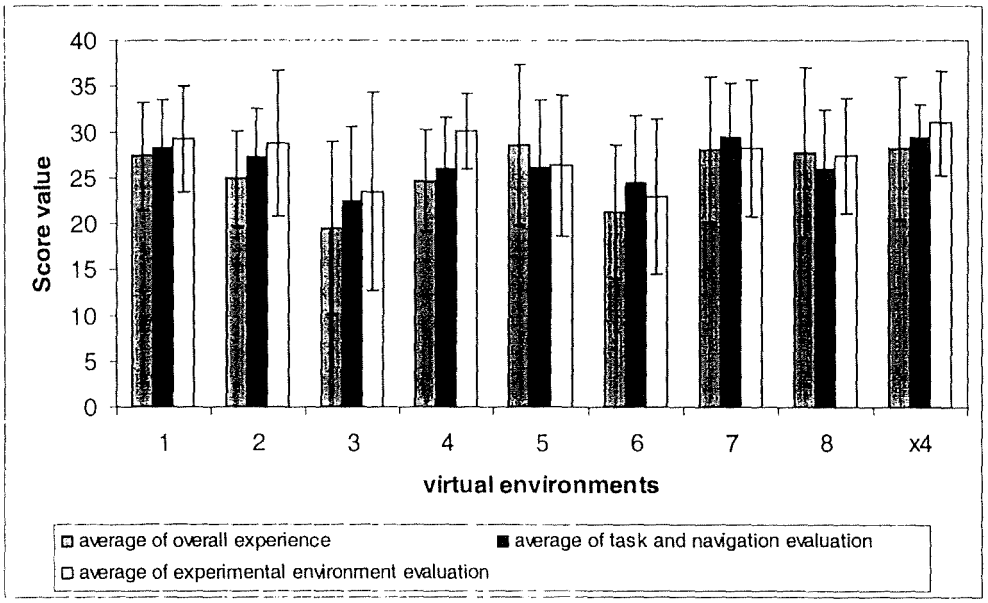

Figure 8- 15 The average subscores value of the excitement questionnaire among the virtual environments in Experiment 5. The subscores measured the excitement level of the participants towards the overall experience during the experiment, experimental environment, and the task and navigation. The data for plotting this graph was from the virtual environments designed from the OA design and the VE_best. Bars denoted ± 1 standard deviation.

Table 8- 9 The descriptive statistics of the responses of excitement questionnaire among the virtual environments in Experiment 5. The subscores measured the excitement level of the participants towards the overall experience during the experiment, experimental environment, and the task and navigation. The data for plotting this graph was from the virtual environments designed from the OA design and the VE_best. Bars denoted ± 1 standard deviation.

Excitement level of the overall experience	Experimental environments	Gender	Average value	Standard deviation	Median value	1st quartile	3rd quartile
	1	M	31.2	2.77	31.00	29.00	34.00
		F	23.6	5.73	24.00	19.00	27.00
		Overall	27.4	5.83	28.50	24.75	31.00
	2	M	27.8	4.44	31.00	24.00	31.00
		F	22	4.47	21.00	20.00	23.00
		Overall	24.9	5.20	23.50	21.25	30.50
	3	M	20.4	12.01	17.00	14.00	29.00
		F	18.6	7.23	19.00	14.00	25.00
		Overall	19.5	9.40	18.00	14.00	25.75
	4	M	25.6	6.23	29.00	21.00	30.00
		F	23.8	5.40	24.00	22.00	24.00
		Overall	24.7	5.58	24.00	21.25	29.75
	5	M	31.6	9.07	36.00	29.00	36.00
		F	25.6	8.38	26.00	18.00	30.00
		Overall	28.6	8.82	29.50	20.00	36.00
	6	M	18.6	7.02	22.00	17.00	23.00
		F	24	7.18	23.00	23.00	26.00
		Overall	21.3	7.27	23.00	18.25	23.75
	7	M	30	6.12	28.00	25.00	36.00
		F	26.2	9.60	26.00	20.00	30.00
		Overall	28.1	7.85	27.00	24.25	34.50
	8	M	30	9.14	33.00	26.00	37.00
		F	25.6	9.84	29.00	25.00	31.00
		Overall	27.8	9.25	30.00	25.25	33.75
	X4	M	25.8	8.14	24.00	21.00	32.00
		F	30.8	7.36	35.00	31.00	35.00
		Overall	28.3	7.78	31.50	21.75	35.00

Excitement level towards the task and navigation	Experimental environments	Gender	Average value	Standard deviation	Median value	1st quartile	3rd quartile
	1	M	32.6	2.70	32.00	31.00	33.00
		F	24	3.16	23.00	22.00	25.00
		Overall	28.3	5.31	29.50	23.50	31.75
	2	M	27.4	3.91	28.00	25.00	31.00
		F	27	7.07	24.00	22.00	33.00
		Overall	27.2	5.39	26.50	22.50	31.00
	3	M	22.2	11.48	23.00	17.00	29.00
		F	22.8	3.70	23.00	21.00	24.00
		Overall	22.5	8.05	23.00	18.75	27.00
	4	M	29.6	2.70	30.00	28.00	31.00
		F	22.4	5.50	22.00	20.00	23.00
		Overall	26	5.58	27.00	22.25	30.75
	5	M	28.2	3.83	28.00	25.00	31.00
		F	24	9.90	24.00	18.00	28.00

		Overall	26.1	7.42	26.50	24.00	30.25
	6	M	22	9.14	25.00	24.00	26.00
		F	26.8	4.60	30.00	24.00	30.00
		Overall	24.4	7.28	25.50	24.00	29.75
	7	M	30	6.36	30.00	24.00	33.00
		F	28.8	6.30	30.00	26.00	31.00
		Overall	29.4	6.00	30.00	24.50	32.50
	8	M	26.4	4.83	24.00	23.00	30.00
		F	25.4	8.47	28.00	23.00	30.00
		Overall	25.9	6.52	26.00	23.00	30.00
	X4	M	30.4	3.36	30.00	29.00	32.00
		F	28.4	4.10	27.00	27.00	32.00
		Overall	29.4	3.69	29.50	27.00	32.00

	Experimental environments	Gender	Average value	Standard deviation	Median value	1st quartile	3rd quartile
	1	M	33.8	1.92	34.00	33.00	35.00
		F	24.6	4.39	26.00	21.00	28.00
		Overall	29.2	5.81	30.00	26.50	33.75
	2	M	30.8	5.54	31.00	30.00	35.00
		F	26.6	9.99	24.00	21.00	30.00
		Overall	28.7	7.93	30.00	22.50	34.00
	3	M	25.4	13.85	32.00	16.00	34.00
		F	21.6	7.96	18.00	16.00	25.00
		Overall	23.5	10.83	21.50	16.00	33.50
	4	M	30	5.34	31.00	30.00	34.00
Excitement		F	30.2	3.27	32.00	29.00	32.00
level		Overall	30.1	4.18	31.50	29.25	32.75
towards the	5	M	26.4	8.38	28.00	24.00	29.00
experimental		F	26.4	7.92	26.00	24.00	28.00
environment		Overall	26.4	7.69	27.00	24.00	28.75
	6	M	22.6	10.83	24.00	19.00	31.00
		F	23.4	6.50	27.00	21.00	28.00
		Overall	23	8.43	25.50	19.50	28.00
	7	M	30.8	6.53	33.00	26.00	36.00
		F	25.8	8.14	22.00	20.00	33.00
		Overall	28.3	7.44	29.50	22.00	35.25
	8	M	29.8	3.96	32.00	26.00	33.00
		F	25	7.68	28.00	25.00	28.00
		Overall	27.4	6.29	28.00	25.25	32.00
	X4	M	29.2	5.07	28.00	26.00	31.00
		F	32.8	6.30	35.00	33.00	36.00
		Overall	31	5.72	32.00	26.50	35.75

8.7. Discussion

8.7.1. Testing of hypotheses

8.7.1.1. Effects of sensory-related variables on level of sense-of-presence (SOP)

H3-1 hypotheses that field-of-view, imposed time delay, view mode, audio and display resolution had significant effect on the SOP that participants experienced. Table 8-10 shows the effects of these sensory variables on SOP. As shown in this table, main effect of audio had significant effect on the CHRPQ II audio subscale ($p<0.05$) and gender had significant effect on the CHRPQ II resolution subscale ($p<0.1$). The interaction between gender and display resolution had significant effect on natural and haptic subscale of CHRPQ II ($p<0.05$), effect of FOV*view mode on CHRPQ II interface quality was marginally significant ($p<0.1$) and effects of FOV*imposed time delay on natural subscale of CHRPQ II ($p<0.05$). The SOP measured by CHRSQ shows that there was neither significant main effects nor interaction effects of sensory related variables on SOP (Table 8-11).

To summarize the effects of sensory-related variables on SOP, audio and gender were the main effects and interaction effects gender* display resolution, FOV* view mode and FOV*imposed time delay. The mean auditory subscale in the 3D auditory condition was 13.5 with a standard error

of 1.0. The mean auditory subscale in the 1D auditory condition was 10.95 with 1.0 standard error. The mean resolution subscale of male participants was 7.78 with a standard error of 0.61. The mean resolution subscale of female participants was 6.25 with a standard error of 0.61. The interaction effects are shown in Figures 8-16 to 8-19.

Table 8- 10. ANOVA table of the CHRPQ II scores from the OA design virtual environments in Experiment 3. IC: involved/control, N: natural, IQ: interface quality, A: auditory, H: haptic, R: resolution, Total: total scores.

Source	*Dependent Variable*	*Sum of Squares*	*df*	*Mean Square*	*F-value*	*Sig.*
GENDER	involved/control	273.800	1	273.800	1.955	.167
	natural	8.450	1	8.450	.308	.581
	interface quality	36.450	1	36.450	1.702	.197
	auditory	.612	1	.612	.025	.875
	haptic	3.200	1	3.200	.355	.553
	resolution	46.513	1	46.513	3.199	.078
	total score	1044.013	1	1044.013	2.621	.110
Field-of-view (FOV)	involved/control	192.200	1	192.200	1.373	.246
	natural	33.800	1	33.800	1.231	.271
	interface quality	16.200	1	16.200	.756	.388
	auditory	.312	1	.312	.013	.910
	haptic	7.200	1	7.200	.800	.374
	resolution	17.113	1	17.113	1.177	.282
	total score	775.013	1	775.013	1.946	.168
Imposed time delay	involved/control	1.250	1	1.250	.009	.925
	natural	5.000E-02	1	5.000E-02	.002	.966
	interface quality	3.200	1	3.200	.149	.700
	auditory	37.813	1	37.813	1.552	.217
	haptic	.000	1	.000	.000	1.000
	resolution	2.113	1	2.113	.145	.704
	total score	3.613	1	3.613	.009	.924
FOV*imposed time delay	involved/control	273.800	1	273.800	1.955	.167
	natural	110.450	1	110.450	4.024	.049
	interface quality	6.050	1	6.050	.282	.597
	auditory	30.013	1	30.013	1.232	.271
	haptic	.450	1	.450	.050	.824
	resolution	9.113	1	9.113	.627	.431
	total score	1058.513	1	1058.513	2.658	.108
View mode	involved/control	22.050	1	22.050	.157	.693
	natural	22.050	1	22.050	.803	.373
	interface quality	14.450	1	14.450	.675	.414
	auditory	35.112	1	35.112	1.441	.234
	haptic	2.450	1	2.450	.272	.604
	resolution	15.313	1	15.313	1.053	.309
	total score	90.313	1	90.313	.227	.636
FOV*view mode	involved/control	16.200	1	16.200	.116	.735
	natural	4.050	1	4.050	.148	.702
	interface quality	72.200	1	72.200	3.371	.071
	auditory	25.313	1	25.313	1.039	.312
	haptic	24.200	1	24.200	2.688	.106
	resolution	15.313	1	15.313	1.053	.309
	total score	40.613	1	40.613	.102	.750
Audio	involved/control	54.450	1	54.450	.389	.535
	natural	.200	1	.200	.007	.932
	interface quality	16.200	1	16.200	.756	.388
	auditory	285.012	1	285.012	11.696	.001
	haptic	12.800	1	12.800	1.422	.237
	resolution	56.113	1	56.113	3.860	.540
	total score	374.112	1	374.112	.939	.336

Display resolution	involved/control	5.000	1	5.000	.036	.851
	natural	.200	1	.200	.007	.932
	interface quality	6.050	1	6.050	.282	.597
	auditory	10.513	1	10.513	.431	.514
	haptic	4.050	1	4.050	.450	.505
	resolution	1.012	1	1.012	.070	.793
	total score	10.513	1	10.513	.026	.871
GENDER * FOV	involved/control	92.450	1	92.450	.660	.419
	natural	4.050	1	4.050	.148	.702
	interface quality	.200	1	.200	.009	.923
	auditory	4.513	1	4.513	.185	.668
	haptic	6.050	1	6.050	.672	.415
	resolution	1.250E-02	1	1.250E-02	.001	.977
	total score	143.113	1	143.113	.359	.551
gender * imposed time delay	involved/control	51.200	1	51.200	.366	.547
	natural	9.800	1	9.800	.357	.552
	interface quality	16.200	1	16.200	.756	.388
	auditory	1.513	1	1.513	.062	.804
	haptic	8.450	1	8.450	.938	.336
	resolution	2.813	1	2.813	.193	.661
	total score	94.613	1	94.613	.238	.628
gender * view mode	involved/control	33.800	1	33.800	.241	.625
	natural	9.800	1	9.800	.357	.552
	interface quality	6.050	1	6.050	.282	.597
	auditory	63.013	1	63.013	2.586	.113
	haptic	3.200	1	3.200	.355	.553
	resolution	25.313	1	25.313	1.741	.192
	total score	103.513	1	103.513	.260	.612
gender * audio	involved/control	156.800	1	156.800	1.120	.294
	natural	2.450	1	2.450	.089	.766
	interface quality	24.200	1	24.200	1.130	.292
	auditory	30.013	1	30.013	1.232	.271
	haptic	2.450	1	2.450	.272	.604
	resolution	2.113	1	2.113	.145	.704
	total score	59.513	1	59.513	.149	.700
gender * display resolution	involved/control	162.450	1	162.450	1.160	.285
	natural	120.050	1	120.050	4.374	.040
	interface quality	36.450	1	36.450	1.702	.197
	auditory	23.113	1	23.113	.948	.334
	haptic	39.200	1	39.200	4.354	.041
	resolution	6.613	1	6.613	.455	.502
	total score	1044.013	1	1044.013	2.621	.110
Error	involved/control	9242.100	66	140.032		
	natural	1811.600	66	27.448		
	interface quality	1413.650	66	21.419		
	auditory	1608.325	66	24.369		
	haptic	594.250	66	9.004		
	resolution	959.525	66	14.538		
	total score	26286.525	66	398.281		
Corrected Total	involved/control	10577.550	80			
	natural	2137.000	80			
	interface quality	1667.550	80			
	auditory	2155.187	80			
	haptic	707.950	80			
	resolution	1158.988	80			
	total score	31127.987	80			

Table 8- 11 ANOVA table of the CHRSQII total score from the OA design virtual environments in Experiment 3

Source	Sum of Squares	df	Mean Square	F-value	Sig.
Field-of-view (FOV)	0.0125	1	0.0125	0.0066	0.9355
Imposed time delay	0.1125	1	0.1125	0.05941	0.80822
FOV*imposed time delay	0.1125	1	0.1125	0.05941	0.80822
View mode	2.8125	1	2.8125	1.48515	0.22744
FOV*view mode	0.3125	1	0.3125	0.16502	0.68593
Audio	0.1125	1	0.1125	0.05941	0.80822
Display resolution	0.6125	1	0.6125	0.32343	0.57154
gender	2.8125	1	2.8125	1.48515	0.22744
FOV * gender	1.5125	1	1.5125	0.79868	0.37484
Imposed time delay * gender	1.5125	1	1.5125	0.79868	0.37484
FOV*imposed time delay* gender	1.0125	1	1.0125	0.53465	0.46733
View mode * gender	0.1125	1	0.1125	0.05941	0.80822
FOV*view mode * gender	4.5125	1	4.5125	2.38284	0.12761
audio * gender	0.6125	1	0.6125	0.32343	0.57154
Display resolution * gender	1.0125	1	1.0125	0.53465	0.46733
Error	121.2	64	1.89375		
Total	487	80			

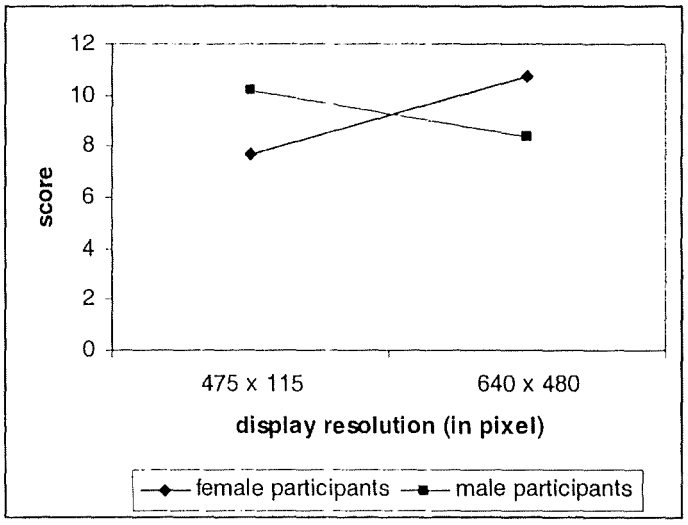

Figure 8- 16 Effects between gender and display resolution on CHRPQ II natural subscale in Experiment 3

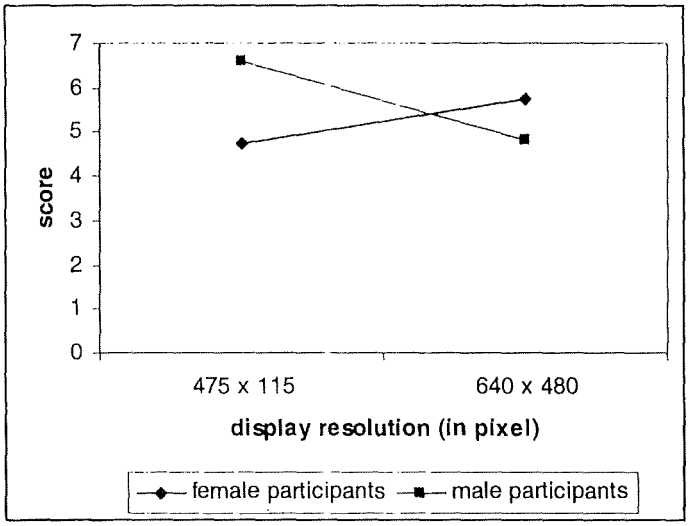

Figure 8- 17 Effects between gender and display resolution on CHRPQ haptic subscale in Experiment 3

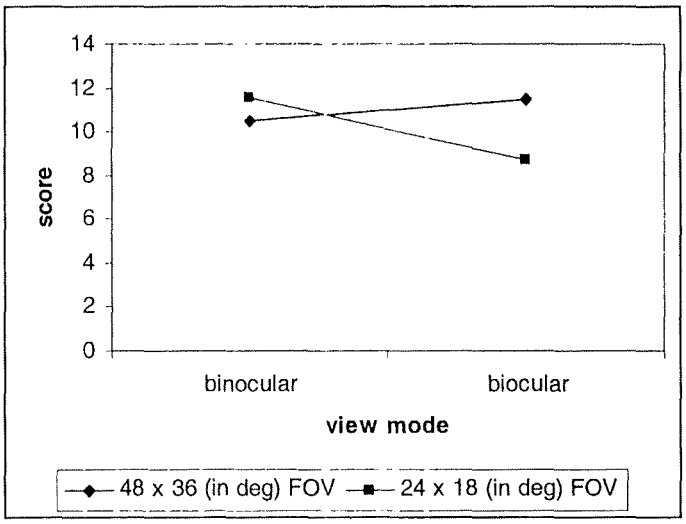

Figure 8- 18 Effect between field-of-view (FOV) and view mode on CHRPQII interface quality in Experiment 3

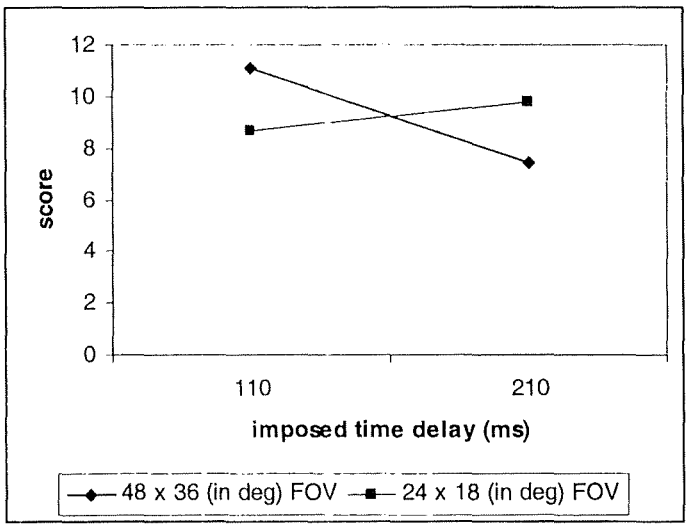

Figure 8- 19 Effect between field-of-view (FOV) and imposed time delay on CHRPQII natural in Experiment 3

8.7.1.2. Effects of sensory related variables on moving cylinder task completion time

Table 8-12 shows the ANOVA summary table for the effects of sensory related variables on the moving cylinder task completion time. The effect of imposed time delay was statistically significant with $p<0.05$. However there was no significant effect of view mode found on this measurement which was against H3-2b. There were no interaction effects on moving cylinder completion time. The mean moving cylinder completion time in the 210 ms imposed time delay was 9.0 minutes with a standard error of 0.7 minutes. The mean moving cylinder completion time in the 110ms imposed time delay was 6.6 minutes with a standard error of 0.7 mimutes.

Table 8- 12 ANOVA table of the moving cylinder completion time from the OA design virtual environments in Experiment 3

Source	*Sum of Squares*	*df*	*Mean Square*	*F-value*	*Sig.*
Gender	7331.477	1	7331.477	2.160808	0.146469
Field-of-view (FOV)	4279.755	1	4279.755	1.261373	0.265587
imposed time delay	16180.42	1	16180.42	4.76886	0.032651
FOV*imposed time delay	118.864	1	118.864	0.035033	0.852119
view mode	1529.539	1	1529.539	0.450801	0.504371
FOV*view mode	1435.997	1	1435.997	0.423232	0.517658
audio	250.6741	1	250.6741	0.073881	0.786642
display resolution	1521.071	1	1521.071	0.448306	0.505549
Gender * FOV	7618.493	1	7618.493	2.2454	0.138929
Gender * FOV*imposed time delay	3095.043	1	3095.043	0.912203	0.343124
Gender * imposed time delay	10.08004	1	10.08004	0.002971	0.956702
Gender * view mode	946.8143	1	946.8143	0.279055	0.599148
Gender * FOV*view mode	149.1376	1	149.1376	0.043955	0.834603
Gender * audio	1425.007	1	1425.007	0.419993	0.519259
Gender * display resolution	550.5533	1	550.5533	0.162265	0.688422
Error	217147.7	64	3392.933		
Total	958380.3	80			

8.7.1.3. Effects of sensory related variables on visual search completion time

The ANOVA summary table for the effects of sensory related variables on time to complete the visual search task is shown in Table 8-13. The effects of FOV and display resolution were statistically significant ($p<0.05$) and no interaction effects were found. This result agreed with the Hypotheses H3-3 in Section 8.5. The mean time for completing the visual search task in 48 x 36 (deg) FOV was 30.1s with a standard error of 13.8s. The mean time for

completing the visual search task in 24 x 18 (deg) FOV was 41.7s with a standard error of 20.7s. The mean time for completing the visual search task in 640 x 480 (display resolution in pixel) was 33.2 s with a standard error of 20.5s. The mean time for completing the visual search task in 475 x 115 (display resolution in pixel) was 38.6s with a standard error of 18.3s.

Table 8- 13 ANOVA table of visual search completion time from the OA design virtual environments in Experiment 5

Source	*Sum of Squares*	*df*	*Mean Square*	*F-value*	*Sig.*
Gender	83864065	1	83864065	0.684	0.411
Field-of-view (FOV)	2.7E+09	1	2.7E+09	22.065	0
Imposed time delay	2.48E+08	1	2.48E+08	2.023	0.16
FOV * imposed time delay	45390468	1	45390468	0.37	0.545
View mode	59543123	1	59543123	0.486	0.488
FOV*view mode	20053786	1	20053786	0.164	0.687
Audio	88410651	1	88410651	0.722	0.399
Display resolution	5.86E+08	1	5.86E+08	4.78	0.032
Gender* FOV	541986.7	1	541986.7	0.004	0.947
Gender * imposed time delay	2.32E+08	1	2.32E+08	1.893	0.174
Gender * view mode	12110154	1	12110154	0.099	0.754
Gender * audio	1.75E+08	1	1.75E+08	1.426	0.237
Gender * display resolution	12070890	1	12070890	0.099	0.755
Error	8.09E+09	66	1.23E+08		
Total	1.15E+11	80			

8.7.1.4. Effects of gender on cybersickness level and performance

Table 8-14 to 8-17 show the effects of gender and sensory related variables on cybersickness level measured by SSQ. Refer to ANOVA tables for task performance (Table 7-13 and 7-14) and with the ANOVA tables for the SSQ result, gender effect was not statistically significant on cybersickness level and performance ($p<0.05$).

Table 8- 14 ANOVA table of the (post-pre) nausea subscore measured by SSQ from the OA design virtual environments in Experiment 3

Source	*Sum of Squares*	*df*	*Mean Square*	*F-value*	*Sig.*
Field-of-view (FOV)	88.121	1	88.121	.070	.791
Imposed time delay	605.793	1	605.793	.485	.489
FOV*imposed time delay	.787	1	.787	.001	.980
View mode	584.417	1	584.417	.467	.497
FOV_view mode	2737.970	1	2737.970	2.190	.144
audio	1.757	1	1.757	.001	.970
Display resolution	31.085	1	31.085	.025	.875
gender	3.064	1	3.064	.002	.961
FOV * gender	3742.340	1	3742.340	2.993	.088
Imposed time delay * gender	1328.676	1	1328.676	1.063	.306
View mode * gender	1335.063	1	1335.063	1.068	.305
audio * gender	2027.494	1	2027.494	1.622	.207
Display resolution * gender	3231.076	1	3231.076	2.584	.113
Error	82513.275	66	1250.201		
Corrected Total	98251.573	80			

Table 8- 15 ANOVA table of the (post-pre) oculomotor subscore measured by SSQ from the OA design virtual environments in Experiment 3

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Field-of-view (FOV)	3151.225	1	3151.225	3.979	.050
Imposed time delay	218.391	1	218.391	.276	.601
FOV*imposed time delay	1112.272	1	1112.272	1.404	.240
View mode	192.942	1	192.942	.244	.623
FOV_view mode	330.866	1	330.866	.418	.520
audio	1.704	1	1.704	.002	.963
Display resolution	298.156	1	298.156	.376	.542
gender	133.244	1	133.244	.168	.683
FOV * gender	293.213	1	293.213	.370	.545
Imposed time delay * gender	905.534	1	905.534	1.143	.289
View mode * gender	366.341	1	366.341	.463	.499
audio * gender	3355.217	1	3355.217	4.237	.044
Display resolution * gender	4698.553	1	4698.553	5.933	.018
Error	52270.279	66	791.974		
Corrected Total	124967.670	80			

Table 8- 16 ANOVA table of the (post-pre) disorientation score measured by SSQ from the OA design virtual environments in Experiment 3

Source	*Sum of Squares*	*df*	*Mean Square*	*F-value*	*Sig.*
Field-of-view (FOV)	4729.799	1	4729.799	1.909	.172
Imposed time delay	2111.425	1	2111.425	.852	.359
FOV*imposed time delay	587.856	1	587.856	.237	.628
View mode	677.863	1	677.863	.274	.603
FOV_view mode	4911.783	1	4911.783	1.983	.164
audio	555.756	1	555.756	.224	.637
Display resolution	18.760	1	18.760	.008	.931
gender	241.718	1	241.718	.098	.756
FOV * gender	1385.632	1	1385.632	.559	.457
Imposed time delay * gender	5983.530	1	5983.530	2.416	.125
View mode * gender	1049.984	1	1049.984	.424	.517
audio * gender	8899.501	1	8899.501	3.593	.062
Display resolution * gender	5773.040	1	5773.040	2.331	.132
Error	163481.511	66	2476.993		
Corrected Total	359630.438	80			

Table 8- 17 ANOVA table of the (post-pre) total score measured by SSQ from the OA design virtual environments in Experiment 3

Source	*Sum of Squares*	*df*	*Mean Square*	*F-value*	*Sig.*
Field-of-view (FOV)	2485.588	1	2485.588	1.779	.187
Imposed time delay	857.696	1	857.696	.614	.436
FOV*imposed time delay	511.748	1	511.748	.366	.547
View mode	544.107	1	544.107	.389	.535
FOV_view mode	2334.663	1	2334.663	1.671	.201
audio	56.215	1	56.215	.040	.842
Display resolution	56.215	1	56.215	.040	.842
gender	.692	1	.692	.000	.982
FOV * gender	1800.525	1	1800.525	1.289	.260
Imposed time delay * gender	2492.076	1	2492.076	1.784	.186
View mode * gender	1054.573	1	1054.573	.755	.388
audio * gender	5123.516	1	5123.516	3.667	.060
Display resolution * gender	5855.210	1	5855.210	4.191	.045
Error	92212.489	66	1397.159		
Corrected Total	220094.886	80			

8.7.1.5. Effects of sense of touch on moving cylinder task completion time

Comparing the time for moving cylinder task completion between TE and OA design VE (1), effect of sense of touch on moving cylinder task completion time could be studied. ANOVA was performed and effect of sense of touch was found which was statistically significant on the time of completing the moving cylinder task ($p<0.1$) (Table 8-18). The mean of completing the moving cylinder task with real sense of touch (i.e. TE environment) was 34s with a standard error of 18.2s. The mean of completing the moving cylinder task in visual and audio cue was 84.8s with a standard error of 18.2s. It shows that by replacing the natural sense of touch by visual and audio cue, the time on completing the moving cylinder task was doubled.

Table 8- 18 ANOVA table of the visual search completion time between TE (x1) and OA design VE(1) in Experiment 3

Source	*Sum of Squares*	*df*	*Mean Square*	*F-value*	*Sig.*
Experimental environment	12900.447	1	12900.447	3.900	.066
Gender	4209.566	1	4209.566	1.273	.276
Experimental environment * gender	88.157	1	88.157	.027	.872
Error	52919.369	16	3307.461		
Total	140638.913	20			

8.7.1.6. Effects of sense of touch on cybersickness level

By comparing the (post-pre) SSQ score between TE and OA design VE (1), effect of sense of touch on cybersickness level that participants experienced could be studied.

Tables 8-19 to 8-21 show the ANOVA table for the effects of sense of touch on SSQ subscores which are nausea, oculomotor and disorientation. Inspections from these 3 tables, effects of gender nor sense of touch on cybersickness level could not be found. In Table 7-23 which shows the ANOVA table for the effects of sense of touch on SSQ total score, the effects of gender and sense of touch could not be found either.

Table 8- 19 ANOVA table for the effects of sense of touch (TE vs. OA design VE (1) on SSQ nausea subscore in Experiment 3.

Source	*Sum of Squares*	*df*	*Mean Square*	*F-value*	*Sig.*
EXPERIMENTAL ENVIRONMENT	113.764	1	113.764	.133	.720
GENDER	550.620	1	550.620	.644	.434
EXPERIMENTAL ENVIRONMENT * GENDER	368.597	1	368.597	.431	.521
Error	13688.145	16	855.509		
Total	20295.587	20			

Table 8- 20 ANOVA table for the effects of sense of touch (TE vs. OA design VE (1) on SSQ oculomotor subscore in Experiment 3.

Source	*Sum of Squares*	*df*	*Mean Square*	*F-value*	*Sig.*
EXPERIMENTAL ENVIRONMENT	2416.042	1	2416.042	1.861	.191
GENDER	646.385	1	646.385	.498	.491
EXPERIMENTAL ENVIRONMENT * GENDER	2.873	1	2.873	.002	.963
Error	20776.234	16	1298.515		
Total	34531.296	20			

Table 8- 21 ANOVA table for the effects of sense of touch (TE vs. OA design VE (1) on SSQ disorientation subscore in Experiment 3.

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
EXPERIMENTAL ENVIRONMENT	2799.924	1	2799.924	.739	.403
GENDER	3497.484	1	3497.484	.923	.351
EXPERIMENTAL ENVIRONMENT * GENDER	242.208	1	242.208	.064	.804
Error	60610.130	16	3788.133		
Total	88551.245	20			

Table 8- 22 ANOVA table for the effects of sense of touch (TE vs. OA design VE (1) on SSQ total score in Experiment 3.

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
EXPERIMENTAL ENVIRONMENT	1819.087	1	1819.087	.927	.350
GENDER	1416.245	1	1416.245	.722	.408
EXPERIMENTAL ENVIRONMENT * GENDER	118.195	1	118.195	.060	.809
Error	31399.364	16	1962.460		
Total	49054.513	20			

8.7.1.7. Effects of sense of touch on CHRPQ II haptic subscale and total score

Table 8-23 shows the effects of sense of touch on CHRPQ II haptic subscale and total score. In order to study this effect, comparison was done between TE and OA design VE (1). As the data did not follow normal distribution, non-parametric test, Mann-Whitney test, was used. Results showed that sense of touch had no statistically significant effect found in CHRPQ II haptic subscale nor in the total score.

Table 8- 23 Mann-Whitney table for the effects of sense of touch on CHRPQ II haptic subscale and total score in Experiment 3

Sources	*CHRPQ II haptic subscale*	*CHRPQ II total score*
Mann-Whitney U	8.500	4.000
Z	-.849	-1.776
Asymp. Sig. (2-tailed)	.396	.076
Exact Sig. [2*(1-tailed Sig.)]	.421	.95

8.7.1.8. Correlation between sense-of-presence (SOP) and performance

H3-5 (Section 8.5) hypotheses that SOP would correlated with performance. A Pearson correlation procedure was performed between the SOP measured by CHRPQ II and CHRSQ, and completion time of moving cylinder task and visual search task. There was no significant correlation found between both SOP measurements with the completion time of moving cylinder task and visual search task ($p>0.05$). This hinted that SOP was not necessarily correlated with performance.

8.7.1.9. Correlation between excitement level and sense-of-presence (SOP)

Hypothesis H3-7 stated the excitement would be correlated with SOP. From this experiment, there was significant positive correlation between the sense of presence measured by CHRPQ II with the level of enjoyment that the participants felt (overall experience: $r=0.307$, $p<0.01$; tasks evaluation $r= 0.394$, $p<0.01$; environment evaluation $r= 0.338$, $p<0.01$). There was also significant positive correlation between the sense of presence measured by CHRSQ with the level of enjoyment that the participants felt (overall experience: $r=0.226$, $p<0.05$; tasks evaluation $r=0.2$, $p<0.01$; environment evaluation $r=0.236$, $p<0.05$). This implied that presence adds the quality of virtual reality technique usage and it contributed to the virtual reality application later.

8.7.1.10. Correlation between CHRPQ II and CHRSQ result

As both questionnaires were used to measure sense of presence, they were expected to be correlated (H3-8). By using Pearson's correlation test, the sense of presence of CHRPQ II was significantly weak correlated with sense of presence measured by CHRSQ ($r=0.23$, $p<0.05$).

8.7.2. Summary

Although there were no significant of sensory related variables on the total score of both CHRPQ II and CHRSQ which were against the hypotheses H3-1, there were significant effects of sensory related variables were found on other subscales of CHRPQ II which mean that there were sensory variables statistically significant affected the SOP. The main effects on affecting SOP were audio and gender ($p<0.05$) and the interaction effects gender* display resolution, FOV* view mode and FOV*imposed time delay.

There was only imposed time delay affecting the moving cylinder task time significantly ($p<0.05$). By reducing the imposed time delay from 210ms to 110 ms, the task completion time was shorted by 36%. Effect of sense of touch was only found in moving cylinder task time but not in SOP nor cybersickness. Participants in the without natural sense of touch environment, the time of completing the moving cylinder task was double (Section 8.7.1.5).

The main effects of FOV and display resolution had significant effect on the visual search completion time ($p<0.05$). Larger FOV and higher resolution could shorten the search time by 30% significantly (Section 8.7.1.3).

In this experiment, no relationship was found between sense-of- presence (SOP) and task performance. This indicated a modification on the existing

model (Section 8.5) between SOP and task performance needed. However the relationship between excitement and SOP was found significantly positive and this further confirmed that excitement added value to SOP.

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* 3 (FOV) x 3 (imposed time delay) x 3 (image quality) x 3 (display resolution) x 2 (sense of touch) x 2 (auditory) x 2 (view mode)=648 experimental environments

CHAPTER 9

DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

This chapter discusses the results with respect to the Presence Questionnaire presented using Cooper-Harper technique and the relationships among sense-of-presence (SOP), task performance, cybersickness and excitement as functions of different sensory variables. The conclusions and the recommendations for the future works are also presented

9.1. Discussions

9.1.1. Presenting the existing questionnaire, the Presence Questionnaire, using Cooper-Harper technique

The existing presentation format of the Presence Questionnaire (PQ, Singer and Witmer, 1996) is Likert 7-point rating scale. Results of Experiment 1 suggested that participants would avoid selecting extreme ratings (i.e. rating 1 or rating 7) on a Likert scale even though these ratings were the appropriate answers. In order to encourage the participants on choosing the extreme ratings when it is appropriate to do so, Cooper-Harper technique was adapted to present the PQ. Eighteen out of the thirty-two questions in the PQ had been identified as having extreme ratings (i.e. ratings 1 or 7) as their appropriate answers if the participants were exposed to a real environment without restriction in field-of-view (e.g., RE_weight). For the participants exposed to the RE_weight environment, the eighteen selected PQ questions presented in Cooper-Harper style resulted in greater percentage of extreme rating selections than the eighteen questions presented using the original 7-point scale. However it should be noted with

caution that the PQ presented in Cooper-Harper style also affected the ratings reported by the participants in the VE conditions. This could well be due to the supplement examples added for clarifying the meanings of the questions. It is possible that when some of the participants faced with these examples, they limited the scope of the questions to the given examples and selected a rating biased towards the examples.

9.1.2. The relationships among the sense-of-presence (SOP), task performance, cybersickness and excitement

Significant negative correlation was found between sense-of-presence (SOP) and cybersickness ($p<0.05$) and there was significant positive correlation between SOP and excitement ($p<0.05$). The significant relationship between excitement and SOP further strengthen the idea of excitement enhances SOP. This finding can further contribute to the game developers on developing 3D games which can increase the players' involvement with the games and at the same time growing interested in them. However there was no significant relationship between SOP and task performance as expected. This raised some doubts on the previous findings indicated that participants with high level of SOP could have better task performance. However the tasks in this study were simple visual search tasks and visual motor tasks.

9.2. Conclusions

With regard to the objectives of this study stated in Section 1.5, the conclusions one may draw from this research is:

(1) When the Cooper-Harper presentation technique was adapted to present the Presence Questionnaire, (PQ, Singer and Witmer, 1996) and the Slater's Questionnaire, evidences indicating benefits as well as drawback

were found. These evidences have been analysed and documented as roadmaps for further development.

(2) There was no relationship found between sense-of-presence (SOP) and task performance and this implied that the participants rated a high level of SOP did not necessarily achieved a high level of performance. A positive relationship exists between the levels of SOP and the levels of excitement reported by the participants. In fact, level of excitement was found to be a more sensitive measure than SOP.

9.3. Future Work Recommendations

(1) Individual differences such as gender and concentration ability may have large effects on rated levels of sense-of-presence (SOP) and should be investigated.

(2) The laboratory setting may cause a biased result on rated levels of SOP and should be studied.

(3) Implement the idea of Kano map (Nariaki, 1984) in relating SOP, excitement, cybersickness and performance could yield interesting results. In other words, we could treat the virtual environment as a product and determine the relationship patterns between the characteristics of a virtual environment and (i) the levels of SOP and excitement (i.e. positive feeling towards the virtual environments), (ii) the levels of cybersickness (i.e. negative feeling towards the virtual environments), and (iii) the levels of performance (i.e. neutral). These relationship patterns could be similar to the patterns suggested in the Kano map theory.

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APPENDIX 2.1 The used Presence Questionnaire (PQ) in this study

Presence Questionnaire (PQ) (Witmer and Singer, 1996) was developed to measure the degree of sense of presence (SOP) within the environment. The reliability for PQ is 0.88. There are totally 32 questions in a 7-point scale and divided into 6 subscales. These 6 subscales are Involved/Control, Natural, Interface Quality, Auditory, Haptic and Resolution, and a Total Score. The main 3 subscales are Involved/Control, Natural and Interface Quality. Involved/Control has questions that related to how the participants feel about their ability to control events. Natural is about the extent to which the interactions felt natural, the extent to which the VE was consistent with reality, and how natural the movement control was. The Interface Quality addresses whether the controls interfere or distract from task performance, whether the display interfered or distracted them from task performance, and the extent to which they felt able to concentrate on the tasks.

Originally PQ is used for measuring subjective sense of presence in virtual environments, in order to make it also applicable in other environments, some modifications are done. For example, 'virtual environment' was changed into 'experimental environment'.

In the following appendices (appendix 2.1a, 2.1b, 2.1c and 2.1d), the four used PQs were listed. These PQs were the PQ with Chinese translations on different terms which was used in Experiment 1(Appendix 2.1a), the PQ questions in Chinese translations (Appendix 2.1b), the PQ presented in Cooper-Harper rating style (CHRPQ used in Experiment 2, Appendix 2.1c) and the modified version of CHRPQ which was the CHRPQ II used in Experiment 3 (Appendix 2.1d). The first introduced PQ, the PQ with

translations on different terms, was used in Experiment 1 only. The PQ in Chinese translations was given to the participants only when they had problems on understanding the English in PQ and was used throughout the whole study when needed. The CHRPQ II which was PQ expressed in Cooper-Harper rating style but with further explanations on words. The method of score calculations for all of the used PQ in this study was according to the instructions listed in Singer and Witmer (1996) and explained as below.

Scoring for Presence Questionnaire (PQ) is as followed:

Total Score: summation of 1, 2, 3, 4, 6, 7, 8, 9, 10, 14, 15, 16, 18, 19*, 20, 21, 22*, 23*, 24

Involved/Control: summation of 1, 2, 4, 7, 9, 10, 14, 18, 19*, 20 and 21

Natural: summation of 3, 6, 8

Interface Quality: summation of 22*, 23* and 24

Auditory: summation of 5, 11, 12

Haptic: summation of 13, 17

Resolution: summation of 15, 16

* Reversed score counted

Appendix 2.1a PQ with Chinese translations on different terms

Presence Questionnaire

Characterize your experience in the experimental environment, by marking an "X" in the MIDDLE of the appropriate box of the 7-point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer.
WITH REGARD TO THE EXPERIMENTAL ENVIRONMENT

1. How much were you able to control events?

Not At All Somewhat Completely

2. How responsive was the experimental environment to actions that you initiated (or performed)? (你身處的環境對你所作的行動有沒有反應 ?)

Not Responsive Moderately Responsive Completely Responsive

3. How natural did your interactions with the experimental environment seem?

Extremely Artificial Borderline Completely Natural

4. How much did the visual aspects of the experimental environment involve you?
(環境中的視覺效果能使你投入嗎 ?)

Not at all Somewhat Completely

5. How much did the auditory aspects of the experimental environment involve you?

Not at all Somewhat Completely

6. How natural was the mechanism (e.g. the Glove & Headset) which controlled movement (i.e. hand and finger movement, head movement) through the experimental environment?
(在環境中用來控制活動的機制有多自然?)

Extremely Artificial Borderline Completely Natural

7. How compelling was your sense of objects moving through space? (你對物件在空間移動的感覺有多強烈?)

Not at all — Moderately Compelling — Very Compelling

8. How much did your experiences (i.e. the things you see, you touch and hear etc) in the experimental environment seem consistent with your real-world experiences (i.e. your normal physical world experience)?

Not Consistent — Moderately Consistent — Very Consistent

9. Were you able to anticipate what would happen next (the physical response of the objects in the experimental environment) in response to the actions that you performed (e.g. move an object)?

Not at all — Somewhat — Completely

10. How completely were you able to actively survey or search the experimental environment using vision?

Not at all — Somewhat — Completely

11. How well could you identify sounds?

Not at all — Somewhat — Completely

12. How well could you localize sounds?

Not at all — Somewhat — Completely

13. How well could you actively survey or search the experimental environment using touch?

Not at all — Somewhat — Completely

14. How compelling was your sense of moving around inside the experimental environment? (e.g. you can turn your head to look at different object)

Not at all — Moderately Compelling — Very Compelling

15. How closely were you able to examine objects? (你能很仔細地觀察物件嗎?)

Not at all Pretty Closely Very Closely

16. How well could you examine objects from multiple viewpoints? (你能用多個角度來觀察物件嗎?)

Not at all Somewhat Extensively

17. How well could you move or manipulate objects in the experimental environment?

Not at all Somewhat Extensively

18. How involved were you in the experimental environment experience?

Not Involved Mildly Involved Completely Engrossed

19. How much (time) delay did you experience between your (physical) actions (e.g. the moment you move your hand) and expected outcomes (the moment you saw your hand move)?

No Delays Moderate Delays Long delays

20. How quickly did you adjust to experimental environment experience?

Not at all Slowly Less than 1 min.

21. How proficient (純熟) in moving and interacting with the experimental environment (as well as the objects inside the environment) did you feel at the end of the experience?

Not Proficient Reasonably Proficient Very Proficient

22. How much did the restriction of vision or visual display quality (if any) interfere or distract you from performing assigned tasks or required activities?

Not at all Interfered Somewhat Prevented Task Performance

23. How much did the control devices (e.g. the Glove) interfere with the performance of assigned tasks or with other activities?

Not at all Interfered Somewhat Interfered Greatly

24. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms (e.g. the Glove) used to perform those tasks or activities? (In other words, if the Glove is very natural that it does not distract you at all, then you should choose "Completely")

Not at all Somewhat Completely

25. How completely were your senses engaged in this (experimental) experience?

Not Engaged Mildly Engaged Completely Engaged

26. To what extent did events occurring outside the experimental environment (e.g. instructions from speaker) distract from your experience in the experimental environment?

Not at all Moderately Very Much

27. Overall, how much did you focus on the use of Headset and control device (i.e. the Glove) instead of the experience of the environment and experimental tasks?

Not at all Somewhat Very Much

28. Were you involved in the experimental task to the extent that you lost track of time (失去時間的觀念)?

Not at all Somewhat Completely

29. How easily was it to identify objects through physical interaction; like touching an object, walking over a surface, or bumping into a wall or object?

Impossible Moderately Difficult Very Easy

30. Were there moments during the experimental environment experience when you felt completely focused on the task or environment?

None Occasionally Frequently

31. How easily did you adjust to the control device (e.g. the Glove) used to interact with the experimental environment?

Difficult Moderate Easily

32. Was the information provided through different sense (i.e. what you see, hear, touch etc) in the experimental environment (e.g., vision, hearing, touch) consistent? (在你身處環境中所提供的訊息是否与你觀能感覺 (視. 聽. 觸) 吻合?)

Not Consistent — Somewhat Consistent — Very Consistent

Appendix 2.1b PQ questions in Chinese translations

1. 你對事情的控制程度有多少?

2. 你身處的環境對你所作的行動有沒有反應?

3. 你和身處的環境的互動動作自然嗎?

4. 環境中的視覺效果能使你投入嗎 ?

5. 環境中的聽覺效果能使你投入嗎 ?

6. 在環境中用來控制活動的機制有多自然?

7. 你對物件在空間移動的感覺有多強烈?

8. 你覺得在身處環境與現實世界的經歷有多接近?

9. 在多大程度上,你能夠預料自己行為所產生的結果?

10. 你能夠用視覺完全主動地觀察及搜索環境嗎?

11. 你對辨別聲音有多好 ?

12. 你能否辨別聲音來源的位置?

13. 你能夠用觸覺來完全主動地觀察及搜索環境嗎?

14. 在身處的環境中,你對移動的感覺有多強烈?

15. 你能夠很仔細地觀察物件嗎 ?

16. 你能用多個角度來觀察物件嗎 ?

17. 在身處環境裏,你能否隨心所欲地移動及操控物件?

18. 你對身處的環境有多投入?

19. 你覺得你的動作與預期的後果有多少時間上的延誤?

20. 你要多少時間才能夠適應你所身處的環境?

21. 在實驗的尾段,你對身處環境的移動及互動能力有多純熟?

22. 視野限制或視覺界面的質素有否防礙或擾亂你執行工作及要求的活動?

23. 控制器有否影響你所執行的工作及其他活動?

24. 你能否集中於執行被指派的工作而不受到執行工作時的機制所影響?

25. 你對身處環境的融入感有多少?

26. 在你身處環境以外正發生的事情,有否打擾你在身處環境中的經歷?

27. 總括來說,你有多投入使用顯示器及控制器而不在身處環境中或工作中?

28. 你是否太投入實驗的工作而失去時間觀念?

29. 你是否能容易地靠觸角來辨認物件?

30. 在身處的環境中,你曾否感到完全地投入工作環境裏?

(如接觸物件,走過物件表面或撞到牆和物件?)

31. 你是否很容易適應控制器之運作來與身處環境交流呢?

32. 在你身處環境中提供的訊息是否與你官能感覺(視,聽,觸)一致?

Appendix 2.1c PQ presented using the Cooper-Harper technique (Cooper-Harper rating Presence Questionnaire: CHRPQ)

WITH REGARD TO THE EXPERIMENTAL ENVIRONMENT. Answer the questions independently in the order that they appear. **Do not skip questions or return to a previous question to change your answer.**
Before answering the questions, pay attention to these following references:
(1) All of the questions refer to YOUR EXPERIENCE in the Experimental Environment that you have just immersed in.
(2) A 'Completely Natural' experience in an Experimental Environment refers to the experience that is the SAME as the daily experience that you have in the normal physical world in which you live in everyday.

Please read and answer each question with CARE because you CANNOT go back on the previous question. If you do not understand any question, PLEASE ASK the experimenter. Please DO NOT GUESS as this will SERIOUSLY affect the accuracy of the data and will DELAY the graduation of the experimenter.

(1) The overall question is "How much were you able to control events?"

Now, please answer a few multi-choice questions in relation to the above overall question:

1a. Were you NOT able to control any event (e.g. move an object or select your view) in the experimental environment? Y/N (Yes = Not able at all)
If Yes -> 1 "Not at all", If No, ask Q1b

1b. Were you able to control event in a similar way as you could in the normal physical world? Y/N
If No, then choose one of the following (please real all 3 options before choosing):
(A) I was close to NOT being able to control events in the experimental environment (ans=2)
(B) I could just BARELY able to control events in the experimental environment. (ans. = 3)
(C) I could SOMEWHAT able to control events in the experimental environment (ans. = 4).
If Yes, then choose one of the following (please read all 3 options before choosing):
(A) I COULD control events BUT NOT AS GOOD AS in the normal physical world (ans. = 5).
(B) I could MORE-OR-LESS COMPLETELY control events similar to what I could in the normal physical world (ans. = 6).
(C) I could COMPLETELY control event JUST LIKE I could in the normal physical world (ans. = 7).

2. The overall question is "How responsive was the experimental environment to actions that you initiated (or performed)? (e.g. when you pick up an object, will that object be picked up by you)
(你身處的環境對你所作的行動有沒有反應?)

Now, please answer a few multi-choice questions in relation to the above overall question:

2a. Was the experimental environment or objects inside the environment responsive AT ALL (e.g. did your view follow your head movement at all)? Y/N (No = Not responsive at all)

If No -> ans. = 1 "Not responsive", If Yes, ask Q2b
2b. Did the experimental environment have a similar level of responsiveness as the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The experimental environment was CLOSE to NOT responsive (ans. = 2)
(B) The experimental environment was SLIGHTLY responsive (ans. = 3)
(C) The experimental environment was MODERATELY responsive (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):
(A) The experimental environment was responsive BUT NOT AS GOOD AS in the normal physical world (ans. = 5).
(B) The experimental environment was MORE-OR-LESS COMPLETELY responsive similar to the normal physical world (ans. = 6)
(C) The experimental environment was COMPLETELY responsive JUST LIKE the normal physical world (ans. = 7).

3. The overall question is " How natural did your interactions with the experimental environment seem?"

Now, please answer a few multi-choice questions in relation to the above overall question

3a. Were your interactions with the experimental environment or objects inside the environment TOTALLY different from the interactions with the normal physical world (examples of interactions include the way to pick up an object)? Y/N

Yes = Totally different No = Not totally different

If Y -> ans. =1 'Extremely artificial', If No, ask Q3b

3b. Were your interactions with the experimental environment bear some similarity with your interactions with the normal physical world (examples of interactions include the way to pick up an object)? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) Your interactions with the experimental environment was ARTIFICIAL (ans. = 2)
(B) Your interactions with the experimental environment was NOT artificial but NOT natural either (ans. = 3)
(C) Your interactions with the experimental environment was BORDERLINE NATURAL (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) Your interactions with the experimental environment was QUITE natural BUT NOT AS GOOD AS in the normal physical world (ans. = 5)
(B) Your interactions with the experimental environment was MORE–OR-LESS COMPLETELY natural similar to just like in the normal physical world (ans. = 6)
(C) Your interactions with the experimental environment was COMPLETELY natural JUST LIKE in the normal physical world (ans. = 7)

(4) How much did the visual aspects of the experimental environment involve you? (環境中的視覺效果能使你投入嗎?)

Now, please answer a few multi-choice questions in relation to the above overall question:

4a. Did the visual aspects of the experimental environment involve you AT ALL? Y/N

4b. Did the visual aspects of the experimental environment help you to feel that you were inside or were a part of the experimental environment? Y/N

If answers to both Q4a and Q4b are No -> ans. =1 'Not at all"
If Yes in either one or both, ask Q4c

4c. Did the visual aspects of the experimental environment involve you or help you to feel that you were actually inside or were a part of the experimental environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The visual aspects of the experimental environment DID NOT really involve me (ans. = 2)
(B) The visual aspects of the experimental environment just BARELY involve me (ans. = 3)
(C) The visual aspects of the experimental environment did SOMEWHAT involve me (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The visual aspects of the experimental environment did involve me BUT NOT AS GOOD AS the visual aspects in the normal physical world (ans. =5)
(B) The visual aspects of the experimental environment did MORE-OR-LESS COMPLETELY involve me similar to the visual aspects in the normal physical world (ans. = 6)
(C) The visual aspects of the experimental environment COMPLETELY involved me JUST LIKE the visual aspects in the normal physical world (ans. = 7)

(5) The overall question is "How much did the auditory aspects of the experimental environment involve you?"

Now, please answer a few multi-choice questions in relation to the above overall question:

5a. Did the auditory (sound) aspects of the experimental environment involve you AT ALL? Y/N

5b. Did the auditory (sound) aspects of the experimental environment help you to feel that you were inside or were a part of the experimental environment? Y/N

If answers to both Q5a and Q5b are No -> ans. = 1 'Not at all'
If Yes to either one or both, ask 5c

5c. Did the auditory aspects of the experimental environment involve you or help you to feel that you were actually inside or were a part of the experimental environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The auditory aspects of the experimental environment DID NOT really involve me (ans. = 2)
(B) The auditory aspects of the experimental environment just BARELY involve me (ans. = 3)
(C) The auditory aspects of the experimental environment did SOMEWHAT involve me (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The auditory aspects of the experimental environment did involve me BUT NOT AS GOOD AS the visual aspects in the normal physical world (ans. =5)
(B) The auditory aspects of the experimental environment did MORE-OR-LESS COMPLETELY involve me similar to the auditory aspects in the normal physical world (ans. = 6)
(C) The auditory aspects of the experimental environment COMPLETELY involved me JUST LIKE I am in the normal physical world (ans. = 7)

6. The overall question is "How natural was the mechanism which controlled movement through the experimental environment?" (Besides navigation, examples of movements can include hand and finger movements, head movements...etc) (在環境中用來控制活動的機制有多自然?)

Now, please answer a few multi-choice questions in relation to the above overall question:

6a. Were the movement-control MECHANISM in the experimental environment TOTALLY different from those in the normal physical world (Besides navigation, ex examples of movements can include hand and finger movements, head movements...etc)? Y/N

Yes = Totally different No = Not totally different

If Yes -> ans. = 1 " Extremely artificial", If No, ask Q6b

6b. Were the movement-control MECHANISM in the experimental environment bear some similarity with that in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The movement-control mechanism in the experimental environment was ARTIFICIAL (ans. = 2)
(B) The movement-control mechanism in the experimental environment was NOT artificial but NOT natural either (ans. = 3)
(C) The movement-control mechanism in the experimental environment was BOREDERLINE NATURAL (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The movement-control mechanism in the experimental environment was QUITE natural BUT NOT AS GOOD AS that in the normal physical world (ans. = 5)
(B) The movement-control mechanism with the experimental environment was MORE-OR-LESS COMPLETELY natural similar to that in the normal physical world (ans. = 6)
(C) The movement-control mechanism with the experimental environment was COMPLETELY natural JUST LIKE in the normal physical world (ans. = 7)

(8) The overall question is "How much did your experiences in the experimental environment seem consistent with your real-world experiences?" (Examples of real-world experiences include the experiences associated with the ways you see, touch or hear and manipulate objects in the normal physical world)

Now, please answer a few multi-choice questions in relation to the above overall question:

8a. Were your experiences in the experimental environment TOTALLY NOT consistent with your real-world experiences? Y/N (Yes = Not consistent)

If Yes -> ans. =1 "Not consistent", If No, ask Q8b

8b. Were your experiences in the experimental environment similar to your real-world experiences? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) Your experiences in the experimental environment were CLOSE to NOT consistent with your real-world experiences (ans. = 2)
(B) Your experiences in the experimental environment was SLIGHTLY consistent with your real-world experience (ans. = 3)
(C) Your experiences in the experimental environment was MODERATELY consistent with your real-world experiences (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) Your experiences in the experimental environment was QUITE consistent with BUT NOT AS GOOD AS your real-world experiences (ans. = 5)
(B) Your experiences in the experimental environment was CONSISTENT but just slightly WORSE than your real-world experiences (ans. = 6)
(C) Your experiences in the experimental environment were VERY consistent and JUST LIKE your real-world experiences (ans. = 7)

(9) The overall question is "Were you able to anticipate what would happen next in response to the actions that you performed?" (E.g. when you use your hand to move an object, that object will be moved in the way you anticipate)?

Now, please answer a few multi-choice questions in relation to the above overall question:

9a. Were you completely NOT able to anticipate the responses of objects to your actions in the experimental environment? Y/N
Yes = Completely NOT able to

If Yes -> ans. = 1 " Not at all", If No, ask Q9b

9b. Were you able to anticipate the responses of objects to your actions in the experimental environment in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I am CLOSE to NOT being able to anticipate how an object would respond to my actions (ans. =2)
(B) In the experimental environment, I could just BARELY able to anticipate how an object would respond to my actions (ans. = 3)
(C) In the experimental environment, I could SOMEWHAT able to anticipate how an object would respond to my actions (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I COULD anticipate how an object would respond to my actions BUT NOT AS WELL AS I could in the normal physical world (ans. = 5)
(B) In the experimental environment, I could MORE-OR-LESS COMPLETELY anticipate how an object would respond to my actions in a similar way as I could in the normal physical world (ans. = 6)
(C) In the experimental environment, I could COMPLETELY anticipate how an object would respond to my actions JUST LIKE I could in the normal physical world (ans. = 7)

(10) The overall question is "How completely were you able to actively survey or search the experimental environment using vision?"

Now, please answer a few multi-choice questions in relation to the above overall question:

10a. Were you TOTALLY NOT able to actively survey or search the experimental environment using vision? Y/N

Yes = Totally not able to

If Yes -> ans. =1 'Not at all", If No, ask Q10b

10b. Were you able to ACTIVELY survey or search the experimental environment using vision in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) I was CLOSE to NOT being able to actively search or survey the experimental environment using vision (ans. = 2)
(B) I could just BARELY able to actively search or survey the experimental environment using vision (ans. = 3)
(C) I could SOMEWHAT able to actively search or survey the experimental environment using vision (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could search or survey the experimental environment in an active way using vision BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE-OR-LESS COMPLETELY search or survey the experimental environment in an active way using vision similar to the way I could in the normal physical world (ans. = 6)
(C) I could COMPLETELY search or survey the experimental environment in an active way using vision JUST LIKE I could in the normal physical world (ans. = 7)

7. The overall is " How compelling was your sense of objects moving through space?" (你對物件在空間移動的感覺有多強烈?)

Now, please answer a few multi-choice questions in relation to the above overall question:

7a. Was the sense of object moving through space in the experimental environment seem compelling to you AT ALL? Y/N

7b. Was the sense of object moving through space in the experimental environment appeared to be real to you? Y/N

If answers to both Q7a and Q7b are No _> ans. =1 "Not at all"
If Yes in either one or both, ask Q7c

7c. Was the sense of object moving through space in the experimental environment appeared to be quite compelling and real to you? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The sense of object moving through space in the experimental environment DID NOT seem to be compelling to me (ans. = 2)
(B) The sense of object moving through space in the experimental environment was just SLIGHTLY compelling to me (ans. = 3)
(C) The sense of object moving through space in the experimental environment was MODERATELY compelling to me (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The sense of object moving through space in the experimental environment was QUITE compelling to me BUT NOT AS GOOD AS that in the normal physical world (ans. =5)
(B) The sense of object through in the experimental environment was COMPELLING to me BUT just slightly LESS compelling than the sense of object moving through space in the normal physical world (ans. = 6)
(C) The sense of object moving through space in the experimental environment was VERY COMPELLING to me JUST LIKE the sense of object moving through space in the normal physical world (ans. = 7)

(11) The overall question is "How well could you identify sounds?" (NB: identify sounds is different from localize sounds e.g., did a human voice sound like a human voice?)

Now, please answer a few multi-choice questions in relation to the above overall question

11a. Were you NOT able to identify any sound in the experimental environment? Y/N (Yes = Not able at all)

If Yes-> ans. =1 'Not at all', if No, ask Q11b

11b. Were you able to identify sounds in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I was CLOSE to NOT being able to identify sounds. (ans. = 2)
(B) In the experimental environment, I could just BARELY able to identify sounds (ans. = 3)
(C) In the experimental environment, I could SOMEWHAT able to identify sounds (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could identify sounds in the experimental environment BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE–OR-LESS COMPLETELY identify sounds in the experimental environment in a similar way as I could in the normal physical world (ans. = 6)
(C) I could COMPLETELY identify sounds in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7)

(12) The overall question is "How well could you localize sounds?"

Now, please answer a few multi-choice questions in relation to the above overall question

12a. Were you NOT able to localize any sound in the experimental environment? (Yes = Not able to)

If Yes-> ans. =1 'Not at all', if No, ask Q12b

12b. Were you able to localize sounds in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I was CLOSE to NOT being able to localize sounds. (ans. = 2)
(B) In the experimental environment, I could just BARELY able to localize sounds (ans. = 3)
(C) In the experimental environment, I could SOMEWHAT able to localize sounds (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could localize sounds in the experimental environment BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE–OR-LESS COMPLETELY localize sounds in the experimental environment in a similar way as I could in the normal physical world (ans. = 6)
(C) I could COMPLETELY localize sounds in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7)

(13) The overall question is "How well could you actively survey or search the experimental environment using touch?" (Touch means physical touch in this study)

Now, please answer a few multi-choice questions in relation to the above overall question

13a. Were you TOTALLY NOT able to actively survey or search the experimental environment using physical touch?
(Yes = totally not able to)

If Yes-> ans. =1 'Not at all', if No, ask Q12b

13b. Were you able to ACTIVELY survey or search the experimental environment using physical touch in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) I was CLOSE to NOT being able to actively survey or search the experimental environment using physical touch (ans. = 2)
(B) I could just BARELY able to actively survey or search the experimental environment using physical touch (ans. = 3)
(C) I could SOMEWHAT able to actively survey or search the experimental environment using physical touch (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could survey or search the experimental environment in an active way using physical touch BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE–OR-LESS COMPLETELY survey or search the experimental environment in an active way using physical touch in a similar way as I could in the normal physical world (ans. = 6)
(C) I could COMPLETELY survey or search the experimental environment in an active way using physical touch JUST LIKE I could in the normal physical world (ans. = 7)

(14) The overall question is "How compelling was your sense of moving around inside the experimental environment?" (E.g., Besides navigation, examples of moving around can also include turning your head or bending your body to look at different objects)

Now, please answer a few multi-choice questions in relation to the above overall question:

14a. Was your sense of moving around in experimental environment seem compelling to you AT ALL? Y/N

14b. Was your sense of moving around in the experimental environment appear to be real to you? Y/N

If answers to both Q14a and Q14b are No -> ans. =1 'Not at all"
If Yes in either one or both, ask Q14c

14c. Was your sense of moving around in the experimental environment appear to be similar to the sense of moving around in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The sense of moving around inside the experimental environment DID NOT seem to be compelling to me (ans. = 2)
(B) The sense of moving around inside the experimental environment was just SLIGHTLY compelling to me (ans. = 3)
(C) The sense of moving around inside the experimental environment was MODERATELY compelling to me (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The sense of moving around inside the experimental environment was QUITE compelling to me BUT NOT AS GOOD AS that in the normal physical world (ans. =5)
(B) The sense of moving around inside the experimental environment was COMPELLING to me BUT just slightly LESS than the sense of moving around in the normal physical world (ans. = 6)
(C) The sense of moving around inside the experimental environment was VERY COMPELLING to me JUST LIKE the sense of moving around in the normal physical world (ans. = 7)

(15) The overall question is "How closely were you able to examine objects?" **(你能很仔細地觀察物件嗎?)**

Now, please answer a few multi-choice questions in relation to the above overall question

15a. Were you able to examine ANY object closely in the experimental environment? Y/N

If No--> ans. =1 'Not at all', If Yes, ask Q15b

15b. Were you able to examine objects closely in the experimental environment in a similar way as you could in the normal physical world (examples of interactions include the way to pick up an object)? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) I was close to NOT being able to examine objects closely in the experimental environment (ans. = 2)
(B) I was just BARELY able to examine objects closely in the experimental environment (ans. = 3)
(C) I was able to examine objects PRETTY CLOSELY in the experimental environment (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could examine objects QUITE closely in the experimental environment BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could examine objects CLOSELY in the experimental environment BUT just slightly WORSE than what I could in the normal physical world (ans. = 6)
(C) I could examine objects VERY CLOSELY in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7)

(16) The overall question is "How well could you examine objects from multiple viewpoints?" (你能用多個角度來觀察物件嗎?) (for example, how well you could turn your head around to examine objects?"

Now, please answer a few multi-choice questions in relation to the above overall question

16a. Were you able to examine objects from more than one viewpoint in the experimental environment? Y/N

If No-> ans. =1 'Not at all', if Yes, ask Q16b

16b. Were you able to examine objects from multiple viewpoints in the experimental environment in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I was CLOSE to NOT being able to examine objects from multiple viewpoints. (ans. = 2)
(B) In the experimental environment, I could just BARELY able to examine objects from multiple viewpoints. (ans. = 3)
(C) In the experimental environment, I could SOMEWHAT able to examine objects from multiple viewpoints. (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could examine objects from multiple viewpoints in the experimental environment BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE–OR-LESS EXTENSIVELY examine objects from multiple viewpoints in the experimental environment in a similar way as I could in the normal physical world (ans. = 6)
(C) I could EXTENSIVELY examine objects from multiple viewpoints in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7)

(17) The overall question is "How well could you move or manipulate objects in the experimental environment?"

Now, please answer a few multi-choice questions in relation to the above overall question

17a. Were you able to move or manipulate ANY object in the experimental environment?

If No-> ans. =1 'Not at all', if Yes, ask Q17b

17b. Were you able to move or manipulate objects in the experimental environment in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I was CLOSE to NOT being able to move or manipulate objects. (ans. = 2)
(B) In the experimental environment, I could just BARELY able to move or manipulate objects. (ans. = 3)
(C) In the experimental environment, I could SOMEWHAT able to move or manipulate objects. (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could move or manipulate objects in the experimental environment BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE-OR-LESS EXTENSIVELY move or manipulate objects at the experimental environment in a similar way as I could in the normal physical world (ans. = 6)
(C) I could EXTENSIVELY move or manipulate objects in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7)

(18) The overall question is "How involved were you in the experimental environment experience?"

Now, please answer a few multi-choice questions in relation to the above overall question:

18a. Did you feel in any way that you were actually INSIDE or were a part of the experimental environment? Y/N

18b. Were you involved in the experimental environment in ANY way? Y/N

If answers to BOTH Q18a and 18b are No -> ans. =1 'Not Involved",
If either one is Yes or both are Yes, ask Q18c

18c. Did you have a reasonable level of involvement with the experimental environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The experimental environment experience DID NOT really involve me (ans. = 2)
(B) The experimental environment experience just BARELY involved me (ans. = 3)
(C) The experimental environment experience did MILDLY involve me (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The experimental environment experience did involve me BUT NOT AS WELL AS my level of involvement with the normal physical world (ans. =5)
(B) The experimental environment experience did MORE-OR-LESS COMPLETELY involve me in a similar way as the normal physical world would (ans. = 6)
(C) The experimental environment experience COMPLETELY Engrossed (i.e., totally involved) me JUST LIKE the normal physical world would (ans. = 7)

(19) The overall question is "How much delay did you experience between your actions and expected outcomes?" (E.g. How much was the time delay that you observed from the moment you moved your hand to the moment that you saw your hand moved)?

Now, please answer a few multi-choice questions in relation to the above overall question

19a. In the experimental environment, was there any observable delay between your actions and expected outcomes? Y/N (No = NO DELAYS – JUST LIKE there is no delay in the normal physical world)

If No -> ans. =1 'No delays', If Y, ask Q19b

19b. In the experimental environment, Did you consider that the delay between your actions and expected outcomes were SHORT? Y/N

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The experimental environment had NEARLY NO delays (ans. = 2)
(B) The experimental environment had SLIGHT DELAYS (ans. = 3)
(C) The experimental environment had MODERATE DELAYS (ans. = 4)

If No, then choose one of the following (please read all 3 options before choosing):

(A) The experimental environment had GREATER than MODERATE DELAYS (ans. = 5)
(B) The experimental environment had MODERATE to LONG DELAYS (ans. = 6)
(C) The experimental environment had LONG DELAYS (ans. = 7)

(20) The overall question is 'How quickly did you adjust to experimental environment experience?'

Now, please answer a few multi-choice questions in relation to the above overall question

20a. Were you TOTALLY NOT able to adjust or adapt to the experimental environment experience AT ALL? Y/N (No = Totally not able to)

If No -> ans. =1 'Not at all, If Yes, ask Q20b

20b. Were you able to adjust to the experimental environment experience in less than 5 minutes? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) I was CLOSE to NOT being able to adjust to the experimental environment experience (ans. = 2)
(B) I was able to adjust to the experimental environment experience in a VERY SLOW way (ans. = 3)
(C) I was able to SLOWLY adjust to the experimental environment experience (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) It took me about 3 to 5 minutes to adjust to the experimental environment experience (ans. = 5)
(B) It took me about 1 to 3 minutes to adjust to the experimental environment experience (ans. = 6)
(C) I was able to adjust to the experimental environment experience in LESS THAN 1 MINUTE (ans. = 7)

(21) The overall question is 'How proficient (純熟) in moving and interacting with the experimental environment did you feel at the end of the experience'

Now, please answer a few multi-choice questions in relation to the above overall question

21a. Towards the end of your experience of the experimental environment, were you able to move your body (e.g., head and hand) and interact with the experimental environment with MUCH DIFFICULTY? Y/N (No = Not much difficulty)

If No -> ans. =1 'Not proficient', If Yes, ask Q21b

21b. Towards the end of your experience of the experimental environment, could you move your body and interact with the experimental environment in a similar level of proficiency as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) My movements and interactions with the experimental environment were CLOSE to NOT PROFICIENT (ans. = 2)
(B) My movements and interactions with the experimental environment were CLOSE to REASONABLE PROFICIENT (ans. = 3)
(C) My movements and interactions with the experimental environment were REASONABLY PROFICIENT (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) My movements and interactions with the experimental environment was QUITE proficient BUT NOT AS PROFICIENT AS in the normal physical world (ans. = 5)
(B) My movements and interactions with the experimental environment were MORE-OR-LESS proficient similar to my movements and interactions with the normal physical world (ans. = 6)
(C) My movements and interactions with the experimental environment were VERY PROFICIENT JUST LIKE my movements and interactions with the normal physical world (ans. = 7)

(22) The overall question is 'How much did the restriction of vision or visual display quality (if any) interfere or distract you from performing assigned tasks or required activities?'

Now, please answer a few multi-choice questions in relation to the above overall question

22a. Did the restriction of vision or visual display quality (if any) interfere or distract you from performing the assigned tasks or required activities in ANY way? Y/N
(No = the restriction (if any) did not affect my tasks in any way)

If No -> ans. =1 'Not at all', If Yes, ask Q22b

22b. Did the restriction of vision or visual display quality SERIOUSLY interfere or distract you from performing the assigned tasks or required activities? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The restriction of vision or visual display quality did NOT REALLY interfere or distract my assigned tasks and activities in the experimental environment (ans. = 2)
(B) The restriction of vision or visual display quality SLIGHTLY interfered or distracted my assigned tasks and activities in the experimental environment (ans. = 3)
(C) The restriction of vision or visual display quality SOMEWHAT interfered or distracted my assigned tasks and activities in the experimental environment (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The restriction of vision or visual display quality INTERFERED or DISTRACTED me from performing the assigned tasks or activities in the experimental environment (ans. = 5)
(B) The restriction of vision or visual display quality SERIOUSLY interfered or distracted me from performing the assigned tasks or activities in the experimental environment (ans. = 6)
(C) The restriction of vision or visual display quality PREVENTED me from performing the assigned tasks or activities in the experimental environment (ans. = 7)

(23) The overall question is 'How much did the control devices (if any) interfere with the performance of assigned tasks or with other activities?' (Examples of control devices (if any) include gloves to measure hand postures, position trackers, headset...etc.)

Now, please answer a few multi-choice questions in relation to the above overall question

23a. Did the control devices GREATLY interfere or distract you from performing the assigned tasks or required activities? Y/N (Yes = greatly interfered)

If Y -> ans. =7 'Interfered greatly, If No, ask Q23b

23b. Did the control devices MILDLY interfere or distract you from performing the assigned tasks or required activities? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The control devices DID NOT interfere or distract me from performing the assigned tasks and activities in the experimental environment (ans. = 1)
(B) The control devices just SLIGHTLY interfered or distracted me from performing the assigned tasks and activities in the experimental environment (ans. = 2)
(C) The control devices MORE-THAN SLIGHTLY interfered or distracted me from performing the assigned tasks and activities in the experimental environment (ans. = 3)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The control devices SOMEWHAT interfered or distracted me from performing the assigned tasks and activities in the experimental environment (ans. = 4)
(B) The control devices INTERFERED or DISTRACTED me from performing the assigned tasks and activities in the experimental environment (ans. = 5)
(C) The control devices were CLOSE to GREATLY interfered or distracted me from performing the assigned tasks and activities in the experimental environment (ans. = 6)

(24) The overall question is 'How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?' (Mechanisms refer to any special apparatus that you had to wear in order to interact with the experimental environment)

Now, please answer a few multi-choice questions in relation to the above overall question

24a. Were you able to concentrate FULLY on the assigned tasks in the experimental environment JUST LIKE you could in the normal physical world? Y/N

If Yes -> 7 "Completely", If No, ask Q24b

24b. Were you able to concentrate MORE on the assigned tasks THAN on the mechanism? Y/N

If No, then choose one of the following (please real all 3 options before choosing):

(A) I could NOT concentrate on the assigned tasks and activities in the experimental environment (ans=1)
(B) I could just BARELY concentrate on the assigned tasks and activities in the experimental environment. (ans. = 2)
(C) I was CLOSE to SOMEWHAT being able to concentrate on the assigned tasks and activities in the experimental environment rather than on the mechanisms (ans. = 3).

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could SOMEWHAT concentrate on the assigned tasks and activities in the experimental environment rather than on the mechanisms (ans. = 4).
(B) I could MORE-THAN SOMEWHAT concentrate on the assigned tasks and activities in the experimental environment rather than on the mechanisms (ans. = 5).
(C) I was CLOSE to COMPLETELY being able to concentrate on the assigned tasks and activities in the experimental environment rather than on the mechanisms (ans. = 7).

(25) The overall question is 'How completely were your senses engaged in this (experimental) experience?' (Examples of senses included touch, visual, auditory senses)

Now, please answer a few multi-choice questions in relation to the above overall question:

25a. Did your senses engage in this experimental experience AT ALL? Y/N

25b. Were you able to see or hear or touch things in the experimental environment? Y/N

If answers to both Q25a and Q25b are No -> ans. =1 'Not Engaged"
If Yes in either one or both, ask Q25c

25c. Were you able to see AND hear AND touch things in the experimental experience? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) My senses DID NOT really engage in the experimental experience (ans. = 2)
(B) My senses just BARELY engaged in the experimental experience (ans. = 3)
(C) My senses were MILDLY engaged in the experimental experience (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) My senses were engaged in experimental experience BUT NOT AS WELL AS I would in the normal physical world (ans. =5)
(B) My senses were MORE-OR-LESS COMPLETELY engaged in the experimental experience in a similar way as in the normal physical world (ans. = 6)
(C) My senses were COMPLETELY engaged in the experimental experience JUST LIKE I would in the normal physical world (ans. = 7)

(26) The overall question is 'To what extent did events occurring outside the experimental environment distract from your experience in the experimental environment?' (An example of events occurring outside the experimental environment is the verbal instructions (if any) from the experimenter during the exposure)

Now, please answer a few multi-choice questions in relation to the above overall question

26a. Did the events occurring outside the experimental environment EVER distract you while you were inside the experimental environment? Y/N

If No -> ans. =1 'Not at all', If Yes, ask Q26b

26b. Did the events occurring outside the experimental environment SERIOUSLY distract you while you were inside the experimental environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The events occurred outside the experimental environment DID NOT really distract me much while I was inside the experimental environment (ans. = 2)
(B) The events occurred outside the experimental environment SLIGHTLY distracted me while I was inside the experimental environment (ans. = 3)
(C) The events occurred outside the experimental environment MODERATELY distracted me while I was inside the experimental environment (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The events occurred outside the experimental environment were causing distractions while I was inside the experimental environment (ans. = 5)
(B) The events occurred outside the experimental environment were causing MUCH distractions while I was inside the experimental environment (ans. = 6)
(C) The events occurred outside the experimental environment distracted me VERY MUCH while I was inside the experimental environment (ans. = 7)

(27) The overall question is 'Overall, how much did you focus on the use of Headset and control devices instead of the experience of the environment and experimental tasks?' (Examples of control devices (if any) include gloves that measure hand postures and position trackers)

Now, please answer a few multi-choice questions in relation to the above overall question

27a. Did you have to wear any Headset and control devices (e.g., gloves, trackers) while you were inside the experimental environment? Y/N

27b. Did you EVER focus on the use of Headset or control devices (if any) while you were inside the experimental environment? Y/N

If EITHER answers to Q27a OR Q27b is No -> ans. =1 'Not at all"
If BOTH answers are Yes , ask Q27c

27c. Did you focus MORE on the use of Headset and control devices THAN on the experimental environment and the assigned tasks? Y/N

If No, then choose one of the following (please real all 3 options before choosing):

(A) I RARELY focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans=2)
(B) I was SLIGHTLY focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans. = 3)
(C) I was SOMEWHAT focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans. = 4).

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I was focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans. = 5).
(B) I was MUCH focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans. = 6).
(C) I was VERY MUCH focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans. = 7).

(28) The overall question is 'Were you involved in the experimental task to the extent that you lost track of time (失去時間的觀念)?'

Now, please answer a few multi-choice questions in relation to the above overall question

28a. Did you EVER loose track of time while you were involved in the experimental tasks? Y/N

If No-> ans. =1 'Not at all', If Yes, ask Q28b

28b. Did you often loose track of time while you were involved in the experimental tasks? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) During the experiment, I DID NOT REALLY loose track of time due to my involvement of the experimental tasks (ans. = 2)
(B) During the experiment, I did SLIGHTLY loose track of time due to my involvement of the experimental tasks (ans. =3)
(C) During the experiment, I was involved in the tasks to the extent that I did SOMEWHAT loose track of time (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) During the experiment, I was involved in the tasks to the extent that I OFTEN lost track of time (ans. = 5)
(B) During the experiment, I was so involved in the tasks that I was CLOSE to COMPLETELY losing track of time (ans. = 6)
(C) During the experiment, I was so involved in the tasks that I COMPLETELY lost track of time (ans. = 7)

(29) The overall question is 'How easily was it to identify objects through physical interaction; like touching an object, walking over a surface, or bumping into a wall or object?'

Now, please answer a few multi-choice questions in relation to the above overall question

29a. Were you able to identify ANY object through your physical interactions in the experimental environment? (No = not able to identify any object)

If No -> 1 "Impossible", If Yes, ask Q29b

29b. Were you able to identify objects through physical interactions inside the experimental environment in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please real all 3 options before choosing):

(A) I was CLOSE to NOT being able to identify objects through physical interactions in the experimental environment (ans=2)
(B) I could identify objects through physical interactions in the experimental environment with SLIGHT DIFFICULTY (ans. = 3)
(C) I could identify objects through physical interactions in the experimental environment with MODERATE DIFFICULTY (ans. = 4).

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could MORE-OR-LESS identify objects through physical interactions in the experimental environment (ans. = 5).
(B) I could identify objects through physical interactions in the experimental environment BUT NOT AS WELL AS I could in the normal physical world (ans. = 6).
(C) I could VERY EASILY identify objects through physical interactions in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7).

(30) The overall question is 'Were there moments during the experimental environment experience when you felt completely focused on the task or environment?'

Now, please answer a few multi-choice questions in relation to the above overall question

30a. Was there ANY moment during the experimental environment experience when you felt completely focused on the task or environment? Y/N (No = none)

If No-> ans. =1 'None', If Yes, ask Q30b

30b. During the experimental environment experience, did you OFTEN feel completely focused on the task or environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) During the experiment, I RARELY felt completely focused on the task or experimental environment (ans. = 2)
(B) During the experiment, I MORE-OR-LESS occasionally felt completely focused on the task or experimental environment (ans. =3)
(C) During the experiment, I OCCASIONALLY felt completely focused on the task or the experimental environment (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) During the experiment, I OFTEN felt completely focused on the task or the experimental environment (ans. = 5)
(B) During the experiment, I MORE-OR-LESS frequently felt completely focused on the task or the experimental environment (ans. = 6)
(C) During the experiment, I FREQUENTLY felt completely focused on the task or the experimental environment (ans. = 7)

(31) The overall question is 'How easily did you adjust to the control devices used to interact with the experimental environment?' (Examples of control devices (if any) can include position trackers and gloves that measure hand postures)

Now, please answer a few multi-choice questions in relation to the above overall question

31a. Can you interact with the experimental environment WITHOUT the use of any control device? Y/N

31b. Can you EASILY adjust to the control devices (if any) used to interact with the experimental environment? Y/N

If EITHER answer is 'Yes', then ? ans. = 7 (Easily), otherwise go to 31c

31c. Did you find it difficult to adjust to the control devices that you used to interact with the experimental environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) I was able to adjust to the control devices that I used to interact with the experimental environment in a FAIRLY easy way (ans. = 6)
(B) I was able to adjust to the control devices that I used to interact with the experimental environment in a MODERATE to EASY way (ans. = 5)
(C) I was able to adjust to the control devices that I used to interact with the experimental environment in a MODERATE way (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I found it MODERATE to DIFFICULT to adjust to the control devices that I used to interact with the experimental environment (ans. = 3)
(B) I found it SLIGHTLY DIFFICULT to adjust to the control devices that I used to interact with the experimental environment (ans. = 2)
(C) I found it DIFFICULT to adjust to the control devices that I used to interact with the experimental environment (ans. =1)

(32) The overall question is 'Was the information provided through different sense in the experimental environment consistent?' (Examples of sense are touch, visual, and auditory) (在你身處環境中所提供的訊息是否与你觀能感覺 (視. 聽. 觸) 吻合?)

Now, please answer a few multi-choice questions in relation to the above overall question:

32a. Was the information provided through different senses in the experimental environment NOT consistent AT ALL? Y/N

IF Yes -> ans. =1 "Not consistent", If No, ask Q32b

32b. Was the information provided through different senses in the experimental environment QUITE CONSISTENT? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The information provided through different senses in the experimental environment was CLOSE to NOT consistent (ans. = 2)
(B) The information provided through different senses in the experimental environment was just BARELY consistent (ans. = 3)
(C) The information provided through different senses in the experimental environment was SOMEWHAT CONSISTENT (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The information provided through different senses in the experimental environment was MORE-OR-LESS consistent (ans. = 5)
(B) The information provided through different senses in the experimental environment was CONSISTENT BUT NOT AS GOOD AS my real-world experiences (ans. = 6)
(C) The information provided through different senses in the experimental environment was VERY CONSISTENT JUST LIKE my real-world experiences (ans. = 7)

-- The end. Thank you for your effort. --

Appendix 2.1d Cooper-Harper rating Presence Questionnaire version II (CHRPQII)

WITH REGARD TO THE EXPERIMENTAL ENVIRONMENT. Answer the questions independently in the order that they appear. **Do not skip questions or return to a previous question to change your answer.**
Before answering the questions, pay attention to these following references:
(3) All of the questions refer to YOUR EXPERIENCE in the Experimental Environment that you have just immersed in.
(4) A 'Completely Natural' experience in an Experimental Environment refers to the experience that is the SAME as the daily experience that you have in the normal physical world in which you live in everyday.

Please read and answer each question with CARE because you CANNOT go back on the previous question. If you do not understand any question, PLEASE ASK the experimenter. Please DO NOT GUESS as this will SERIOUSLY affect the accuracy of the data and will DELAY the graduation of the experimenter.

(2) The overall question is "How much were you able to control events?"

Now, please answer a few multi-choice questions in relation to the above overall question:

1a. Do you agree with the following statement:
The statement is "I could NOT move any object or I could NOT select my view in the experimental environment"

If "agree" --> 1 "Not at all", If "disagree", ask Q1b

1b. Were you able to control event in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please real all 3 options before choosing):

(A) I was close to NOT being able to control events in the experimental environment (ans=2)
(B) I could just BARELY able to control events in the experimental environment. (ans. = 3)
(C) I could SOMEWHAT able to control events in the experimental environment (ans. = 4).

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I COULD control events BUT NOT AS GOOD AS in the normal physical world (ans. = 5).
(B) I could MORE-OR-LESS COMPLETELY control events similar to what I could in the normal physical world (ans. = 6).
(C) I could COMPLETELY control event JUST LIKE I could in the normal physical world (ans. = 7).

(2) The overall question is "How responsive was the experimental environment to actions that you initiated (or performed)? (e.g. when you pick up an object, will that object be picked up by you) (你身處的環境對你所作的行動有沒有反應?)

Now, please answer a few multi-choice questions in relation to the above overall question:

2a. Was the experimental environment or objects inside the environment responsive AT ALL (e.g. did your view follow your head movement at all)? Y/N (No = Not responsive at all)

If No -> ans. = 1 "Not responsive", If Yes, ask Q2b
2b. Did the experimental environment have a similar level of responsiveness as the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The experimental environment was CLOSE to NOT responsive (ans. = 2)
(B) The experimental environment was SLIGHTLY responsive (ans. = 3)
(C) The experimental environment was MODERATELY responsive (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The experimental environment was responsive BUT NOT AS GOOD AS in the normal physical world (ans. = 5).
(B) The experimental environment was MORE-OR-LESS COMPLETELY responsive similar to the normal physical world (ans. = 6)
(C) The experimental environment was COMPLETELY responsive JUST LIKE the normal physical world (ans. = 7).

(3) The overall question is " How natural did your interactions with the experimental environment seem?"

Now, please answer a few multi-choice questions in relation to the above overall question

3a. Were your interactions with the experimental environment or objects inside the environment TOTALLY different from the interactions with the normal physical world (examples of interactions include the way to pick up an object)? Y/N

Yes = Totally different No = Not totally different

If Y -> ans. =1 'Extremely artificial', If No, ask Q3b

3b. Were your interactions with the experimental environment bear some similarity with your interactions with the normal physical world (examples of interactions include the way to pick up an object)? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) Your interactions with the experimental environment was ARTIFICIAL (ans. = 2)
(B) Your interactions with the experimental environment was NOT artificial but NOT natural either (ans. = 3)
(C) Your interactions with the experimental environment was BORDERLINE NATURAL (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) Your interactions with the experimental environment was QUITE natural BUT NOT AS GOOD AS in the normal physical world (ans. = 5)
(B) Your interactions with the experimental environment was MORE–OR-LESS COMPLETELY natural similar to just like in the normal physical world (ans. = 6)
(C) Your interactions with the experimental environment was COMPLETELY natural JUST LIKE in the normal physical world (ans. = 7)

(4) How much did the visual aspects of the experimental environment involve you? (環境中的視覺效果能使你投入嗎?)

Now, please answer a few multi-choice questions in relation to the above overall question:

4a. Did the visual aspects of the experimental environment involve you AT ALL? Y/N

4b. Did the visual aspects of the experimental environment help you to feel that you were inside or were a part of the experimental environment? Y/N

If answers to both Q4a and Q4b are No -> ans. =1 'Not at all"
If Yes in either one or both, ask Q4c

4c. Did the visual aspects of the experimental environment involve you or help you to feel that you were actually inside or were a part of the experimental environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The visual aspects of the experimental environment DID NOT really involve me (ans. = 2)
(B) The visual aspects of the experimental environment just BARELY involve me (ans. = 3)
(C) The visual aspects of the experimental environment did SOMEWHAT involve me (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The visual aspects of the experimental environment did involve me BUT NOT AS GOOD AS the visual aspects in the normal physical world (ans. =5)
(B) The visual aspects of the experimental environment did MORE-OR-LESS COMPLETELY involve me similar to the visual aspects in the normal physical world (ans. = 6)
(C) The visual aspects of the experimental environment COMPLETELY involved me JUST LIKE the visual aspects in the normal physical world (ans. = 7)

(5) The overall question is "How much did the auditory aspects of the experimental environment involve you?"

Now, please answer a few multi-choice questions in relation to the above overall question:

5a. Did the auditory (sound) aspects of the experimental environment involve you AT ALL? Y/N

5b. Did the auditory (sound) aspects of the experimental environment help you to feel that you were inside or were a part of the experimental environment? Y/N

If answers to both Q5a and Q5b are No -> ans. = 1 'Not at all'
If Yes to either one or both, ask 5c

5c. Did the auditory aspects of the experimental environment involve you or help you to feel that you were actually inside or were a part of the experimental environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The auditory aspects of the experimental environment DID NOT really involve me (ans. = 2)
(B) The auditory aspects of the experimental environment just BARELY involve me (ans. = 3)
(C) The auditory aspects of the experimental environment did SOMEWHAT involve me (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The auditory aspects of the experimental environment did involve me BUT NOT AS GOOD AS the visual aspects in the normal physical world (ans. =5)
(B) The auditory aspects of the experimental environment did MORE-OR-LESS COMPLETELY involve me similar to the auditory aspects in the normal physical world (ans. = 6)
(C) The auditory aspects of the experimental environment COMPLETELY involved me JUST LIKE I am in the normal physical world (ans. = 7)

6. The overall question is "How natural was the mechanism which controlled movement through the experimental environment?" (Besides navigation, examples of movements can include hand and finger movements, head movements...etc) (在環境中用來控制活動的機制有多自然?)

Now, please answer a few multi-choice questions in relation to the above overall question:

6a. Were the movement-control MECHANISM in the experimental environment TOTALLY different from those in the normal physical world (Besides navigation, ex examples of movements can include hand and finger movements, head movements...etc)? Y/N

Yes = Totally different No = Not totally different

If Yes -> ans. = 1 " Extremely artificial", If No, ask Q6b

6b. Were the movement-control MECHANISM in the experimental environment bear some similarity with that in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The movement-control mechanism in the experimental environment was ARTIFICIAL (ans. = 2)
(B) The movement-control mechanism in the experimental environment was NOT artificial but NOT natural either (ans. = 3)
(C) The movement-control mechanism in the experimental environment was BOREDERLINE NATURAL (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The movement-control mechanism in the experimental environment was QUITE natural BUT NOT AS GOOD AS that in the normal physical world (ans. = 5)
(B) The movement-control mechanism with the experimental environment was MORE-OR-LESS COMPLETELY natural similar to that in the normal physical world (ans. = 6)
(C) The movement-control mechanism with the experimental environment was COMPLETELY natural JUST LIKE in the normal physical world (ans. = 7)

7. The overall question is " How compelling was your sense of objects moving through space?" (你對物件在空間移動的感覺有多強烈?) (In other words, the overall question is asking "How real and convincing was your sense of objects moving through space?")

Now, please answer a few multi-choice questions in relation to the above overall question:

7a. Was the sense of object moving through space in the experimental environment seem compelling (i.e., real and convincing) to you AT ALL? Y/N

7b. Was the sense of object moving through space in the experimental environment appeared to be compelling (i.e., real and convincing) to you? Y/N

If answers to both Q7a and Q7b are No _> ans. =1 "Not at all"
If Yes in either one or both, ask Q7c

7c. Was the sense of object moving through space in the experimental environment appeared to be quite compelling (i.e., quite real and convincing) to you? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The sense of object moving through space in the experimental environment DID NOT seem to be compelling (i.e., real and convincing) to me (ans. = 2)
(B) The sense of object moving through space in the experimental environment was just SLIGHTLY compelling (i.e., real and convincing) to me (ans. = 3)
(C) The sense of object moving through space in the experimental environment was MODERATELY compelling (i.e., real and convincing) to me (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The sense of object moving through space in the experimental environment was QUITE compelling (i.e., real and convincing) to me BUT NOT AS GOOD AS that in the normal physical world (ans. =5)
(B) The sense of object through in the experimental environment was COMPELLING (i.e., real and convincing) to me BUT just slightly LESS compelling than the sense of object moving through space in the normal physical world (ans. = 6)
(C) The sense of object moving through space in the experimental environment was VERY COMPELLING (i.e., real and convincing) to me JUST LIKE the sense of object moving through space in the normal physical world (ans. = 7)

(8) The overall question is "How much did your experiences in the experimental environment seem consistent with your real-world experiences?" (Examples of real-world experiences include the experiences associated with the ways you see, touch or hear and manipulate objects in the normal physical world)

Now, please answer a few multi-choice questions in relation to the above overall question:

8a. Do you agree with the following statement:
The statement is: "My experiences in the experimental environment were TOTALLY NOT consistent with my real world experiences."

If "agree" -> 1 "Not consistent", If "disagree", ask Q8b

8b. Were your experiences in the experimental environment similar to your real-world experiences? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) Your experiences in the experimental environment were CLOSE to NOT consistent with your real-world experiences (ans. = 2)
(B) Your experiences in the experimental environment was SLIGHTLY consistent with your real-world experience (ans. = 3)
(C) Your experiences in the experimental environment was MODERATELY consistent with your real-world experiences (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) Your experiences in the experimental environment was QUITE consistent with BUT NOT AS GOOD AS your real-world experiences (ans. = 5)
(B) Your experiences in the experimental environment was CONSISTENT but just slightly WORSE than your real-world experiences (ans. = 6)
(C) Your experiences in the experimental environment were VERY consistent and JUST LIKE your real-world experiences (ans. = 7)

(9) The overall question is "Were you able to anticipate what would happen next in response to the actions that you performed?" (E.g. when you use your hand to move an object, that object will be moved in the way you anticipate)?

Now, please answer a few multi-choice questions in relation to the above overall question:

9a. Do you agree with the following statement:
The statement is " I was COMPLETELY NOT able to anticipate the responses of objects to my actions in the experimental environment."

If "agree"-->1 "Not at all", If "disagree", ask Q9b

9b. Were you able to anticipate the responses of objects to your actions in the experimental environment in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I am CLOSE to NOT being able to anticipate how an object would respond to my actions (ans. =2)
(B) In the experimental environment, I could just BARELY able to anticipate how an object would respond to my actions (ans. = 3)
(C) In the experimental environment, I could SOMEWHAT able to anticipate how an object would respond to my actions (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I COULD anticipate how an object would respond to my actions BUT NOT AS WELL AS I could in the normal physical world (ans. = 5)
(B) In the experimental environment, I could MORE-OR-LESS COMPLETELY anticipate how an object would respond to my actions in a similar way as I could in the normal physical world (ans. = 6)
(C) In the experimental environment, I could COMPLETELY anticipate how an object would respond to my actions JUST LIKE I could in the normal physical world (ans. = 7)

(10) The overall question is "How completely were you able to actively survey or search the experimental environment using vision?"

Now, please answer a few multi-choice questions in relation to the above overall question:

10a. Do you agree with the following statement:
The statement is " I was TOTALLY NOT able to actively survey or search the experimental environment using vision."

If "agree", 1 "Not at all". If "disagree", ask Q10b

10b. Were you able to ACTIVELY survey or search the experimental environment using vision in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) I was CLOSE to NOT being able to actively search or survey the experimental environment using vision (ans. = 2)
(B) I could just BARELY able to actively search or survey the experimental environment using vision (ans. = 3)
(C) I could SOMEWHAT able to actively search or survey the experimental environment using vision (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could search or survey the experimental environment in an active way using vision BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE-OR-LESS COMPLETELY search or survey the experimental environment in an active way using vision similar to the way I could in the normal physical world (ans. = 6)
(C) I could COMPLETELY search or survey the experimental environment in an active way using vision JUST LIKE I could in the normal physical world (ans. = 7)

(11) The overall question is "How well could you identify sounds?" (NB: **identify sounds is different from localize sounds** e.g., did a human voice sound like a human voice?)

Now, please answer a few multi-choice questions in relation to the above overall question

11a. Do you agree with the following statement?
The statement is "I was UNABLE to identify any sound in the experimental environment."

If agree-> ans. =1 'Not at all', if disagree, ask Q11b

11b. Were you able to identify sounds in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I was CLOSE to NOT being able to identify sounds. (ans. = 2)
(B) In the experimental environment, I could just BARELY able to identify sounds (ans. = 3)
(C) In the experimental environment, I could SOMEWHAT able to identify sounds (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could identify sounds in the experimental environment BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE–OR-LESS COMPLETELY identify sounds in the experimental environment in a similar way as I could in the normal physical world (ans. = 6)
(C) I could COMPLETELY identify sounds in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7)

(12) The overall question is "How well could you localize sounds?"

Now, please answer a few multi-choice questions in relation to the above overall question

12a. Do you agree with the following statement?
The statement is " I was UNABLE to tell where the sound is from."

If agree-> ans. =1 'Not at all', if disagree, ask Q12b

12b. Were you able to localize sounds in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I was CLOSE to NOT being able to localize sounds. (ans. = 2)
(B) In the experimental environment, I could just BARELY able to localize sounds (ans. = 3)
(C) In the experimental environment, I could SOMEWHAT able to localize sounds (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could localize sounds in the experimental environment BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE–OR-LESS COMPLETELY localize sounds in the experimental environment in a similar way as I could in the normal physical world (ans. = 6)
(C) I could COMPLETELY localize sounds in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7)

(13) The overall question is "How well could you actively survey or search the experimental environment using touch?" (Touch means physical touch in this study)

Now, please answer a few multi-choice questions in relation to the above overall question

13a. Do you agree with the following statement?
The statement is " I was TOTALLY NOT able to actively survey or search the experimental environment using physical touch."

(Agree = totally not able to) If disagree, then go to Q13b

13b. Were you able to ACTIVELY survey or search the experimental environment using physical touch in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) I was CLOSE to NOT being able to actively survey or search the experimental environment using physical touch (ans. = 2)
(B) I could just BARELY able to actively survey or search the experimental environment using physical touch (ans. = 3)
(C) I could SOMEWHAT able to actively survey or search the experimental environment using physical touch (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could survey or search the experimental environment in an active way using physical touch BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE–OR-LESS COMPLETELY survey or search the experimental environment in an active way using physical touch in a similar way as I could in the normal physical world (ans. = 6)
(C) I could COMPLETELY survey or search the experimental environment in an active way using physical touch JUST LIKE I could in the normal physical world (ans. = 7)

(14) The overall question is "How compelling was your sense of moving around inside the experimental environment?" (NB: Besides navigation, examples of moving around can also include turning your head or bending your body to look at different objects)

Now, please answer a few multi-choice questions in relation to the above overall question:

14a. When you were moving inside the experimental environment, can you CLEARLY sense that you were actually moving? Y/N

14b. Was your sense of moving around in the experimental environment appear to be compelling (i.e., real and convincing) to you? Y/N

If answers to both Q14a and Q14b are No -> ans. =1 'Not at all"
If Yes in either one or both, ask Q14c

14c. Was your sense of moving around in the experimental environment appear to be similar to the sense of moving around in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The sense of moving around inside the experimental environment DID NOT seem to be compelling (i.e., real and convincing) to me (ans. = 2)
(B) The sense of moving around inside the experimental environment was just SLIGHTLY compelling (i.e., real and convincing) to me (ans. = 3)
(C) The sense of moving around inside the experimental environment was MODERATELY compelling (i.e., real and convincing) to me (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The sense of moving around inside the experimental environment was QUITE compelling (i.e., real and convincing) to me BUT NOT AS GOOD AS that in the normal physical world (ans. =5)
(B) The sense of moving around inside the experimental environment was COMPELLING (i.e., real and convincing) to me BUT just slightly LESS than the sense of moving around in the normal physical world (ans. = 6)
(C) The sense of moving around inside the experimental environment was VERY COMPELLING (i.e., real and convincing) to me JUST LIKE the sense of moving around in the normal physical world (ans. = 7)

(15) The overall question is "How closely were you able to examine objects?" **(你能很仔細地觀察物件嗎?)**

Now, please answer a few multi-choice questions in relation to the above overall question

15a. Were you able to examine ANY object closely in the experimental environment? Y/N

If No--> ans. =1 'Not at all', If Yes, ask Q15b

15b. Were you able to examine objects closely in the experimental environment in a similar way as you could in the normal physical world (examples of interactions include the way to pick up an object)? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) I was close to NOT being able to examine objects closely in the experimental environment (ans. = 2)
(B) I was just BARELY able to examine objects closely in the experimental environment (ans. = 3)
(C) I was able to examine objects PRETTY CLOSELY in the experimental environment (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could examine objects QUITE closely in the experimental environment BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could examine objects CLOSELY in the experimental environment BUT just slightly WORSE than what I could in the normal physical world (ans. = 6)
(C) I could examine objects VERY CLOSELY in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7)

(16) The overall question is "How well could you examine objects from multiple viewpoints?" (你能用多個角度來觀察物件嗎?) (for example, how well you could turn your head around to examine objects from different viewpoints?"

Now, please answer a few multi-choice questions in relation to the above overall question

16a. Were you able to examine objects from more than one viewpoint in the experimental environment? Y/N

If No-> ans. =1 'Not at all', if Yes, ask Q16b

16b. Were you able to examine objects from multiple viewpoints in the experimental environment in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I was CLOSE to NOT being able to examine objects from multiple viewpoints. (ans. = 2)
(B) In the experimental environment, I could just BARELY able to examine objects from multiple viewpoints. (ans. = 3)
(C) In the experimental environment, I could SOMEWHAT able to examine objects from multiple viewpoints. (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could examine objects from multiple viewpoints in the experimental environment BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE–OR-LESS EXTENSIVELY examine objects from multiple viewpoints in the experimental environment in a similar way as I could in the normal physical world (ans. = 6)
(C) I could EXTENSIVELY examine objects from multiple viewpoints in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7)

(17) The overall question is "How well could you move or manipulate objects in the experimental environment?"

Now, please answer a few multi-choice questions in relation to the above overall question

17a. Were you able to move or manipulate ANY object in the experimental environment?

If No-> ans. =1 'Not at all', if Yes, ask Q17b

17b. Were you able to move or manipulate objects in the experimental environment in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) In the experimental environment, I was CLOSE to NOT being able to move or manipulate objects. (ans. = 2)
(B) In the experimental environment, I could just BARELY able to move or manipulate objects. (ans. = 3)
(C) In the experimental environment, I could SOMEWHAT able to move or manipulate objects. (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could move or manipulate objects in the experimental environment BUT NOT AS WELL AS in the normal physical world (ans. = 5)
(B) I could MORE–OR-LESS EXTENSIVELY move or manipulate objects at the experimental environment in a similar way as I could in the normal physical world (ans. = 6)
(C) I could EXTENSIVELY move or manipulate objects in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7)

(18) The overall question is "How involved were you in the experimental environment experience?"

Now, please answer a few multi-choice questions in relation to the above overall question:

18a. Did you feel in any way that you were actually INSIDE or were a part of the experimental environment? Y/N

18b. Were you involved in the experimental environment in ANY way? Y/N

If answers to BOTH Q18a and 18b are No -> ans. =1 'Not Involved",
If either one is Yes or both are Yes, ask Q18c

18c. Did you have a reasonable level of involvement with the experimental environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The experimental environment experience DID NOT really involve me (ans. = 2)
(B) The experimental environment experience just BARELY involved me (ans. = 3)
(C) The experimental environment experience did MILDLY involve me (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The experimental environment experience did involve me BUT NOT AS WELL AS my level of involvement with the normal physical world (ans. =5)
(B) The experimental environment experience did MORE-OR-LESS COMPLETELY involve me in a similar way as the normal physical world would (ans. = 6)
(C) The experimental environment experience COMPLETELY Engrossed (i.e., totally involved) me JUST LIKE the normal physical world would (ans. = 7)

(19) The overall question is "How much delay did you experience between your actions and expected outcomes?" (E.g. How much was the time delay that you observed from the moment you moved your hand to the moment that you saw your hand moved)?

Now, please answer a few multi-choice questions in relation to the above overall question

19a. In the experimental environment, was there any observable delay between your actions and expected outcomes? Y/N (No = NO DELAYS – JUST LIKE there is no delay in the normal physical world)

If No -> ans. =1 'No delays', If Y, ask Q19b

19b. In the experimental environment, Did you consider that the delay between your actions and expected outcomes were SHORT? Y/N

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The experimental environment had NEARLY NO delays (ans. = 2)
(B) The experimental environment had SLIGHT DELAYS (ans. = 3)
(C) The experimental environment had MODERATE DELAYS (ans. = 4)

If No, then choose one of the following (please read all 3 options before choosing):

(A) The experimental environment had GREATER than MODERATE DELAYS (ans. = 5)
(B) The experimental environment had MODERATE to LONG DELAYS (ans. = 6)
(C) The experimental environment had LONG DELAYS (ans. = 7)

(20) The overall question is 'How quickly did you adjust to experimental environment experience?'

Now, please answer a few multi-choice questions in relation to the above overall question

20a Do you agree with the following statement?
The statement is " I was TOTALLY NOT able to adjust or adapt to the experimental environment experience AT ALL."

If "agree", 1 "Totally not able to". If "disagree", ask Q20b.

20b. Were you able to adjust to the experimental environment experience in less than 5 minutes? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) I was CLOSE to NOT being able to adjust to the experimental environment experience (ans. = 2)
(B) I was able to adjust to the experimental environment experience in a VERY SLOW way (ans. = 3)
(C) I was able to SLOWLY adjust to the experimental environment experience (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) It took me about 3 to 5 minutes to adjust to the experimental environment experience (ans. = 5)
(B) It took me about 1 to 3 minutes to adjust to the experimental environment experience (ans. = 6)
(C) I was able to adjust to the experimental environment experience in LESS THAN 1 MINUTE (ans. = 7)

(21) The overall question is 'How proficient (純熟) in moving and interacting with the experimental environment did you feel at the end of the experience'

Now, please answer a few multi-choice questions in relation to the above overall question

21a. Do you agree with the following statement?
The statement is " Towards the end of my experience of the experimental environment, I still feel that I am NOT PROFICIENT in moving my body (e.g., head and hand) and interacting with the experimental environment."

If agree , ask Q21 b. If disagree. =1 'Not proficient',

21b. Towards the end of your experience of the experimental environment, could you move your body and interact with the experimental environment in a similar level of proficiency as you could in the normal physical world? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) My movements and interactions with the experimental environment were CLOSE to NOT PROFICIENT (ans. = 2)
(B) My movements and interactions with the experimental environment were CLOSE to REASONABLE PROFICIENT (ans. = 3)
(C) My movements and interactions with the experimental environment were REASONABLY PROFICIENT (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) My movements and interactions with the experimental environment was QUITE proficient BUT NOT AS PROFICIENT AS in the normal physical world (ans. = 5)
(B) My movements and interactions with the experimental environment were MORE–OR-LESS proficient similar to my movements and interactions with the normal physical world (ans. = 6)
(C) My movements and interactions with the experimental environment were VERY PROFICIENT JUST LIKE my movements and interactions with the normal physical world (ans. = 7)

(22) The overall question is 'How much did the restriction of vision or visual display quality (if any) interfere or distract you from performing assigned tasks or required activities?'

Now, please answer a few multi-choice questions in relation to the above overall question

22a. Did the restriction of vision or visual display quality (if any) INTERFERE or DISTRACT you from performing the assigned tasks or required activities in ANY way? Y/N
(No = the restriction (if any) did NOT interfere or distract my tasks in any way)

If No -> ans. =1 'Not at all', If Yes, ask Q22b

22b. Did the restriction of vision or visual display quality SERIOUSLY interfere or distract you from performing the assigned tasks or required activities? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The restriction of vision or visual display quality did NOT REALLY interfere or distract my assigned tasks and activities in the experimental environment (ans. = 2)
(B) The restriction of vision or visual display quality SLIGHTLY interfered or distracted my assigned tasks and activities in the experimental environment (ans. = 3)
(C) The restriction of vision or visual display quality SOMEWHAT interfered or distracted my assigned tasks and activities in the experimental environment (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The restriction of vision or visual display quality INTERFERED or DISTRACTED me from performing the assigned tasks or activities in the experimental environment (ans. = 5)
(B) The restriction of vision or visual display quality SERIOUSLY interfered or distracted me from performing the assigned tasks or activities in the experimental environment (ans. = 6)
(C) The restriction of vision or visual display quality PREVENTED me from performing the assigned tasks or activities in the experimental environment (ans. = 7)

(23) The overall question is 'How much did the control devices (if any) interfere with the performance of assigned tasks or with other activities?' (Examples of control devices (if any) include gloves to measure hand postures, position trackers, headset...etc.)

Now, please answer a few multi-choice questions in relation to the above overall question

23a. Did the control devices GREATLY interfere or distract you from performing the assigned tasks or required activities? Y/N (Yes = greatly interfered)

If Y -> ans. =7 'Interfered greatly, If No, ask Q23b

23b. Did the control devices MILDLY interfere or distract you from performing the assigned tasks or required activities? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The control devices DID NOT interfere or distract me from performing the assigned tasks and activities in the experimental environment (ans. = 1)
(B) The control devices just SLIGHTLY interfered or distracted me from performing the assigned tasks and activities in the experimental environment (ans. = 2)
(C) The control devices MORE-THAN SLIGHTLY interfered or distracted me from performing the assigned tasks and activities in the experimental environment (ans. = 3)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The control devices SOMEWHAT interfered or distracted me from performing the assigned tasks and activities in the experimental environment (ans. = 4)
(B) The control devices INTERFERED or DISTRACTED me from performing the assigned tasks and activities in the experimental environment (ans. = 5)
(C) The control devices were CLOSE to GREATLY interfered or distracted me from performing the assigned tasks and activities in the experimental environment (ans. = 6)

(24) The overall question is 'How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?' (Mechanisms refer to any special apparatus that you had to wear in order to interact with the experimental environment)

Now, please answer a few multi-choice questions in relation to the above overall question

24a. Were you able to concentrate FULLY on the assigned tasks in the experimental environment JUST LIKE you could in the normal physical world? Y/N

If Yes -> 7 "Completely", If No, ask Q24b

24b. Were you able to concentrate MORE on the assigned tasks THAN on the mechanism? Y/N

If No, then choose one of the following (please real all 3 options before choosing):

(A) I could NOT concentrate on the assigned tasks and activities in the experimental environment (ans=1)
(B) I could just BARELY concentrate on the assigned tasks and activities in the experimental environment. (ans. = 2)
(C) I was CLOSE to SOMEWHAT being able to concentrate on the assigned tasks and activities in the experimental environment rather than on the mechanisms (ans. = 3).

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could SOMEWHAT concentrate on the assigned tasks and activities in the experimental environment rather than on the mechanisms (ans. = 4).
(B) I could MORE-THAN SOMEWHAT concentrate on the assigned tasks and activities in the experimental environment rather than on the mechanisms (ans. = 5).
(C) I was CLOSE to COMPLETELY being able to concentrate on the assigned tasks and activities in the experimental environment rather than on the mechanisms (ans. = 7).

(25) The overall question is 'How completely were your senses engaged in this (experimental) experience?' (Examples of senses included touch, visual, auditory senses)

Now, please answer a few multi-choice questions in relation to the above overall question:

25a. Did your senses engage in this experimental experience AT ALL? Y/N

25b. Were you able to see or hear or touch things in the experimental environment? Y/N

If answers to both Q25a and Q25b are No -> ans. =1 'Not Engaged"
If Yes in either one or both, ask Q25c

25c. Were you able to see AND hear AND touch things in the experimental experience? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) My senses DID NOT really engage in the experimental experience (ans. = 2)
(B) My senses just BARELY engaged in the experimental experience (ans. = 3)
(C) My senses were MILDLY engaged in the experimental experience (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) My senses were engaged in experimental experience BUT NOT AS WELL AS I would in the normal physical world (ans. =5)
(B) My senses were MORE-OR-LESS COMPLETELY engaged in the experimental experience in a similar way as in the normal physical world (ans. = 6)
(C) My senses were COMPLETELY engaged in the experimental experience JUST LIKE I would in the normal physical world (ans. = 7)

(26) The overall question is 'To what extent did events occurring outside the experimental environment distract from your experience in the experimental environment?' (An example of events occurring outside the experimental environment is the verbal instructions (if any) from the experimenter during the exposure)

Now, please answer a few multi-choice questions in relation to the above overall question

26a. Did the events occurring outside the experimental environment EVER distract you while you were inside the experimental environment? Y/N

If No -> ans. =1 'Not at all', If Yes, ask Q26b

26b. Did the events occurring outside the experimental environment SERIOUSLY distract you while you were inside the experimental environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(D) The events occurred outside the experimental environment DID NOT really distract me much while I was inside the experimental environment (ans. = 2)

(E) The events occurred outside the experimental environment SLIGHTLY distracted me while I was inside the experimental environment (ans. = 3)

(F) The events occurred outside the experimental environment MODERATELY distracted me while I was inside the experimental environment (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The events occurred outside the experimental environment were causing distractions while I was inside the experimental environment (ans. = 5)

(B) The events occurred outside the experimental environment were causing MUCH distractions while I was inside the experimental environment (ans. = 6)

(C) The events occurred outside the experimental environment distracted me VERY MUCH while I was inside the experimental environment (ans. = 7)

(28) The overall question is 'Overall, how much did you focus on the use of Headset and control devices instead of the experience of the environment and experimental tasks?' (Examples of control devices (if any) include gloves that measure hand postures and position trackers)

Now, please answer a few multi-choice questions in relation to the above overall question

27a. Did you have to wear any Headset and control devices (e.g., gloves, trackers) while you were inside the experimental environment? Y/N

27b. Did you EVER focus on the use of Headset or control devices (if any) while you were inside the experimental environment? Y/N

If EITHER answers to Q27a OR Q27b is No -> ans. =1 'Not at all"
If BOTH answers are Yes , ask Q27c

27c. Did you focus MORE on the use of Headset and control devices THAN on the experimental environment and the assigned tasks? Y/N

If No, then choose one of the following (please real all 3 options before choosing):

(A) I RARELY focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans=2)
(B) I was SLIGHTLY focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans. = 3)
(C) I was SOMEWHAT focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans. = 4).

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I was focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans. = 5).
(B) I was MUCH focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans. = 6).
(C) I was VERY MUCH focused on the use of Headset and control devices instead of the experience of the experimental environment and the tasks (ans. = 7).

(28) The overall question is 'Were you involved in the experimental task to the extent that you lost track of time (失去時間的觀念)?'

Now, please answer a few multi-choice questions in relation to the above overall question

28a. Did you EVER loose track of time while you were involved in the experimental tasks? Y/N

If No-> ans. =1 'Not at all', If Yes, ask Q28b

28b. Did you often loose track of time while you were involved in the experimental tasks? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) During the experiment, I DID NOT REALLY loose track of time due to my involvement of the experimental tasks (ans. = 2)
(B) During the experiment, I did SLIGHTLY loose track of time due to my involvement of the experimental tasks (ans. =3)
(C) During the experiment, I was involved in the tasks to the extent that I did SOMEWHAT loose track of time (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) During the experiment, I was involved in the tasks to the extent that I OFTEN lost track of time (ans. = 5)
(B) During the experiment, I was so involved in the tasks that I was CLOSE to COMPLETELY losing track of time (ans. = 6)
(C) During the experiment, I was so involved in the tasks that I COMPLETELY lost track of time (ans. = 7)

(29) The overall question is 'How easily was it to identify objects through physical interaction; like touching an object, walking over a surface, or bumping into a wall or object?'

Now, please answer a few multi-choice questions in relation to the above overall question

29a. Were you able to identify ANY object through your physical interactions in the experimental environment? (No = not able to identify any object)

If No -> 1 "Impossible", If Yes, ask Q29b

29b. Were you able to identify objects through physical interactions inside the experimental environment in a similar way as you could in the normal physical world? Y/N

If No, then choose one of the following (please real all 3 options before choosing):

(A) I was CLOSE to NOT being able to identify objects through physical interactions in the experimental environment (ans=2)
(B) I could identify objects through physical interactions in the experimental environment with SLIGHT DIFFICULTY (ans. = 3)
(C) I could identify objects through physical interactions in the experimental environment with MODERATE DIFFICULTY (ans. = 4).

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I could MORE-OR-LESS identify objects through physical interactions in the experimental environment (ans. = 5).
(B) I could identify objects through physical interactions in the experimental environment BUT NOT AS WELL AS I could in the normal physical world (ans. = 6).
(C) I could VERY EASILY identify objects through physical interactions in the experimental environment JUST LIKE I could in the normal physical world (ans. = 7).

(30) The overall question is 'Were there moments during the experimental environment experience when you felt completely focused on the task or environment?'

Now, please answer a few multi-choice questions in relation to the above overall question

30a. Was there ANY moment during the experimental environment experience when you felt completely focused on the task or environment? Y/N (No = none)

If No-> ans. =1 'None', If Yes, ask Q30b

30b. During the experimental environment experience, did you OFTEN feel completely focused on the task or environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) During the experiment, I RARELY felt completely focused on the task or experimental environment (ans. = 2)
(B) During the experiment, I MORE-OR-LESS occasionally felt completely focused on the task or experimental environment (ans. =3)
(C) During the experiment, I OCCASIONALLY felt completely focused on the task or the experimental environment (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) During the experiment, I OFTEN felt completely focused on the task or the experimental environment (ans. = 5)
(B) During the experiment, I MORE-OR-LESS frequently felt completely focused on the task or the experimental environment (ans. = 6)
(C) During the experiment, I FREQUENTLY felt completely focused on the task or the experimental environment (ans. = 7)

(31) The overall question is 'How easily did you adjust to the control devices used to interact with the experimental environment?' (Examples of control devices (if any) can include position trackers and gloves that measure hand postures)

Now, please answer a few multi-choice questions in relation to the above overall question

31a. Can you interact with the experimental environment WITHOUT the use of any control device? Y/N

31b. Can you EASILY adjust to the control devices (if any) used to interact with the experimental environment? Y/N

If EITHER answer is 'Yes', then ? ans. = 7 (Easily), otherwise go to 31c

31c. Did you find it difficult to adjust to the control devices that you used to interact with the experimental environment? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) I was able to adjust to the control devices that I used to interact with the experimental environment in a FAIRLY easy way (ans. = 6)
(B) I was able to adjust to the control devices that I used to interact with the experimental environment in a MODERATE to EASY way (ans. = 5)
(C) I was able to adjust to the control devices that I used to interact with the experimental environment in a MODERATE way (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) I found it MODERATE to DIFFICULT to adjust to the control devices that I used to interact with the experimental environment (ans. = 3)
(B) I found it SLIGHTLY DIFFICULT to adjust to the control devices that I used to interact with the experimental environment (ans. = 2)
(C) I found it DIFFICULT to adjust to the control devices that I used to interact with the experimental environment (ans. =1)

(32) The overall question is 'Was the information provided through different sense in the experimental environment consistent?' (Examples of sense are touch, visual, and auditory) (在你身處環境中所提供的訊息是否与你觀能感覺(視. 聽. 觸) 吻合?)

Now, please answer a few multi-choice questions in relation to the above overall question:

32a. Do you agree with the following statement?
The statement is " The information that provided through different senses in the experimental environment was NOT consistent AT ALL."

If "agree", 1 "Not consistent". If " disagree", ask Q32b

32b. Was the information provided through different senses in the experimental environment QUITE CONSISTENT? Y/N

If No, then choose one of the following (please read all 3 options before choosing):

(A) The information provided through different senses in the experimental environment was CLOSE to NOT consistent (ans. = 2)
(B) The information provided through different senses in the experimental environment was just BARELY consistent (ans. = 3)
(C) The information provided through different senses in the experimental environment was SOMEWHAT CONSISTENT (ans. = 4)

If Yes, then choose one of the following (please read all 3 options before choosing):

(A) The information provided through different senses in the experimental environment was MORE-OR-LESS consistent (ans. = 5)
(B) The information provided through different senses in the experimental environment was CONSISTENT BUT NOT AS GOOD AS my real-world experiences (ans. = 6)
(C) The information provided through different senses in the experimental environment was VERY CONSISTENT JUST LIKE my real-world experiences (ans. = 7)

-- The end. Thank you for your effort. --

Appendix 2.2 The details of Slater's Questionnaire and Cooper-Harper rating Slater's Questionnaire

Appendix 2.2.was divided into 3 parts to explain the formation of Cooper-Harper rating Slater's Questionnaire from the Slater's Questionnaire. Appendix 2.2a was a table which illustrated the various versions of Slater's Questionnaires reported over the years. All of the listed Slater's Questionnaires in this appendix were from various found published journal papers.

Appendix 2.2b listed the questions selected from the Slater's Questionnaires in Appendix 2.2a and was used in this study. This group of chosen questions formed the questionnaire called the Slater's Questionnaire here. This Slater's Questionnaire was the base of the later Cooper-Harper rating Slater's Questionnaire.

Appendix 2.2c listed the Cooper-Harper rating Slater's Questionnaire (CHRSQ) used in Experiment 3. This CHRSQ was the Slater's Questionnaire presented in Cooper-Haper rating style.

Appendix 2.2a History of the Published Slater's Questionnaires on measuring sense-of-presence (SOP)

Table A2.2a-1 to Table A2.2a-6 illustrated a list of Dr Slater's published questionnaires which were used on measuring level of sense-of-presence (SOP) that participants experienced during the experiments. All of the responses were in ordinal rating 1 to 7. The order of the listing was in chronological order.

Table A2.2a-1 The questionnaire extracted from the Slater, et al. (1992) on measuring sense-of-presence (SOP)

1. Please rate *your sense of being there* in the computer generated world on the following scale from 1 to 7:	
In the computer generated world I had a sense of "being there"...	Please tick against your answer
1. not at all	1
2	2
3	3
4	4
5	5
6	6
7 very much	7

2. To what event were there times during the experience when the computer-generated world became the "reality" for you, and you almost forgot about the "real world" outside?	
There were times during the experience when the computer generated world became more real or present for me compared to the "real world"...	Please tick against your answer
1. at no time	1

2	2
3	3
4	4
5	5
6	6
7 almost all of the time	7

3. When you think back about your experience, do you think of the computer-generated world more as something that you saw, or more as somewhere that you visited? Please answer on the following 1 to 7 scale.	
The computer generated world seems to me to be more like	Please tick against your answer
1. something that I saw	1
2	2
3	3
4	4
5	5
6	6
7. somewhere that I visited	7

Table A2.2a-2 Questionnaire extracted from Slater, et al. (1993) study on sense-of-presence

1. What extent did you experience a sense of being "really there" inside the virtual environment? 1. Not at all really there 2. There to a small extent 3. There to some extent

4. A definite sense of being there 5. A strong experience of being there 6. Totally there
2. During the experiment you entered a number of different rooms in the virtual environment and carried out some activities. Please write down as much as you can remember about each of the rooms and what you did and what happened in them.
3. Write as much as you want about your overall experiences in the virtual environments. Pay attention to your sense of being there or not, your physical sensations, your mental experiences, your thoughts about what happened – in fact about anything that occurs to you about what you experienced.
4. Were there any circumstances that especially increased your sense of being "really there"? If so write them down, or else write "NONE".
5. Were there any circumstances that especially decreased your sense of being "really there"? If so write them down, or else write "NONE".

Table A2.2a-3 The questionnaire that extracted from the published paper of Barfield, Sheridan, Slater (1995) on measuring sense-of-presence (SOP). All responses were in ordinal scale from 1 to 7

1 To what extent did you experience a sense of being "really there" inside the virtual environment? A little A lot 1 2 3 4 5 6 7
2. Please rate your sense of being there in the computer-generated world... *In the computer-generated world I had a sense of "being there"...* 1. Not at all 7. Very much

3. To what extent were there times during the experience when the computer-generated world became the "reality" for you, and you almost forgot about the "real world" outside?
There were times during the experience when the computer-generated world became more real or presence for me compared to the "real world"...
1. At no time 7. Almost all of the time

4. When you think back about your experience, do you think of the computer-generated world more as something that you saw, or more as somewhere that you visited?
The computer-generated world seems to me to be more like...
1. Something that I saw 7. Somewhere that I visited

5. How realistic was your interaction with the virtual objects?
6. Did the objects in the computer generated world look real?
7. Was the "force feedback" provided by the hand controller realistic?

Table A2.2a-4 Questionnaire that was extracted from Slater, et al., 1998 study. All the responses for this questionnaire were in ordinal rating 1-7.

1. Please rate *your sense of being in the field among the plants*, on the following scale from 1 to 7, where 7 represents your *normal experience of being in a place.*

   I had a sense of "being there" in the field:
   (1) Not at all. (7)Very much.

2. When you think back about your experience, do you think of the virtual field more as images that you saw, or more as somewhere that you visited? Please answer on the following 1 to 7 scale:

   The virtual field seems to me to be more like ...
   (1) Images that I saw. (7) Somewhere that I visited.

3. To what extent were there times during the experience when the field became the "reality" for you, and you almost forgot about the "real world" of the laboratory in which the whole experience was really taking place?

   There were times during the experience when the virtual field became more real for me compared to the "real world" ...
   (1) At no time. (7) Almost all the time.

4. Consider your memory of being in the virtual field. How similar in terms of the structure of the memory of other places you have been today? By "structure of the memory" consider things like the extent to which you have a visual memory of the field, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and

other such structural elements. *I think of the virtual field as a place in a way similar to other places that I've been today ...* 1. Not at all ... 7. Very much so.
5. During the time of the experience, did you often think to yourself that you were actually just standing in an office wearing a helmet or did the field overwhelm you? *During the time of the experience I often thought that I was really standing in the lab wearing a helmet ...* (1) *Most of the time I realized I was in the lab.* (7) *Never because the virtual field overwhelmed me.*
6. During the time of the experience, which was strongest on the whole, your sense of being in the virtual field, or of being in the real world of the laboratory? *I had a stronger sense of being in ...* (1) *The real world of the laboratory.* (7) *The virtual reality of the field of plants.*

Table A2.2a-5 Questionnaire that Dr Slater and Dr Steed developed in 2000 to study the level of sense-of-presence (SOP) that participants experienced. This set of questions was extracted from the published study by Slater and Steed in 2000.

1. Please rate *your sense of being in the field*, on the following scale from 1 to 7, where 7 represents your *normal experience of being in a place.* *I had a sense of "being there" in the field:* (1) Not at all. (7) Very much.

2. When you think back about your experience, do you think of the field more as images that you saw, or more as somewhere that you visited? Please answer on the following 1 to 7 scale:
The virtual field seems to me to be more like ...
(1) Images that I saw. (7) Somewhere that I visited

3. To what extent were there times during the experience when the field became the "reality" for you, and you almost forgot about the "real world" of the laboratory in which the whole experience was really taking place? *There were times during the experience when the virtual field became more real for me compared to the "real world" ...*

(1) At no time. (7) Almost all the time.

4. During the time of the experience, which was strongest on the whole, your sense of being in the field, or of being in the real world of the laboratory?
5.
I had a stronger sense of being in ...
(1) *The real world of the laboratory.* (7) *The virtual reality of the field of plants.*

Table A2.2a-6 Questionnaire on measuring sense-of-presence extracted from the published study Usoh, Armen and Slater (2000).

1. Please rate *your sense of being in the* office space, on the following scale from 1 to 7, where 7 represents *your normal experience of being in a place.*

I had a sense of "being there" in the office space:
(1) Not at all. (7) Very much.

2. Please write down any further comments that you wish to make about your experience. In particular, what things helped to five you a sense of "really being" in the office space, and what things acted to "pull you out" of this?

3. To what extent were there times during the experience when the office space was the reality for you?

There were times during the experience when the office space was the reality for me...
(1) At no time. (7) Almost all the time.

4. When you think back about your experience, do you think of the office space more as *images that you saw*, or more as *somewhere that you visited*?

The office space seems to me to be more like...
(1) Images that I saw. (7) Somewhere that visited.

5. Consider your memory of being in the office space. How similar in terms of the *structure of the memory* is this to the structure of the memory of other *places* you have been today? Be "structure of the memory," consider things like the extent to which you have a visual memory of the office space, whether that memory is in color, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such *structural* elements.

I think of the office space as a place in a way similar to other places that I've been today...

(1) Not at all. (7) Very much so.

6. During the time of the experience, which was strongest on the whole, your sense of being in the office space, or of being elsewhere?

I had a stronger sense of...
(1) Being elsewhere. (7) Being in the office space.

7. During the time of the experience, did you often think to yourself that you were actually in the office space?

During the experience I often thought that I was really standing in the office space...
(1) Not very often. (7) Very much so.

Appendix 2.2b The Slater's questionnaire that is used in this study

The questions that listed in this section were selected from the published questionnaire developed by Dr Slater and his colleagues (Appendix 2.2a). These selected questions were called the Slater's questionnaire and was used in this study. In this section, the questions of the Slater's questionnaire were presented in the original format as in the publishment but with some wordings changed on the place name. For example in the first question listed in below, the original question was "Please rate your *sense of being* in the field, on the following scale from 1 to 7, where 7 represents your normal experience of being in a place." The modified version of this question for this study was "Please rate your *sense of being* in room which is full of Tomb Raider posters, on the following scale from 1 to 7, where 7 represents your normal experience of being in a place." One can noticed that the only differences was on the experimental environment name.

Adapted from Slater and Steed (2000) Question 1:

Please rate *your sense of being in the* room which is full of Tomb Raider posters, on the following scale from 1 to 7, where 7 represents *your normal experience of being in a place.*

I had a sense of "being there" in the room *which is full of Tomb Raiderposters:*

(1) Not at all. (7) Very much.

Adapted from Slater and Steed (2000) Question 2

To what extent were there times during the experience when the room which is full of Tomb Raider posters was the reality for you?

There were times during the experience when the room which is full of xxx posters *was the reality for me...*

(1) At no time. (7) Almost all the time

Adapted from Slater and Steed (2000) Question 2

From Table Q7 (2000b)

When you think back about the time when you were performing tasks in this experiment, do you think of the *room which is full of xxx posters* more as *images that you saw*, or more as *somewhere that you visited*?

The room which is full of Tomb Raider posters seems to me to be more like...

(1) Images that I saw. (7) Somewhere that visited.

Adapted from Dr. Usoh, M., Dr. Catena, Dr. Arman, S. and Dr. Slater(2000) Question 5:

Consider your memory of being in the *room which is full of xxx posters*. How similar in terms of the *structure of the memory* is this to the structure of the memory of other *places* you have been today? Be "structure of the memory," consider things like the extent to which you have a visual memory of the *room which is full of Tomb Raider posters*, whether that memory is in color, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such *structural* elements.

I think of the room which is full of Tomb Raider posters as a place in a way similar to other places that I've been today...

(1) Not at all. (7) Very much so.

Adapted from Slater and Steed (2000) Question 4 :

During the time of the experience, which was strongest on the whole, your sense of being in the *room which is full of Tomb Raider posters*, or of being elsewhere?

I had a stronger sense of...

(1) Being elsewhere. (7) Being in the room which is full of Tomb Raider posters space.

Adapted from Slater and Steed (2000) Question 5 :

During the time of the experience, did you often think to yourself that you were actually in the *room which is full of xxx posters*?

During the experience I often thought that I was really in the room which is full of Tomb Raider posters...

(1) Not very often. (7) Very much so.

Adapted from Dr. Usoh, M., Dr. Catena, Dr. Arman, S. and Dr. Slater(2000) Open Question

Please write down any further comments that you wish to make about your experience related to the room which is full of posters. In particular, what things helped to five you a sense of "really being" in the *room which is full of Tomb Raider posters*, and what things acted to "pull you out" of this?

Adapted from Slater, et al., (1993) Open Question

During the experiment you entered a *room which is full of Tomb Raider posters* and carried out some activities. Please write down as much as you can remember about that room and what you did and what happened in it.

Adapted from Slater, et al., (1993) Open Question

Write as much as you want about your overall experiences in the *room which is full of Tomb Raider posters.* Pay attention to your sense of being there or not, your physical sensations, your mental experiences, your thoughts about what happened – in fact about anything that occurs to you about what you experienced.

Appendix 2.2c The Slater's Questionnaire presented using Cooper-Harper technique

The Slater's Questionnaire listed in Appendix 2.2b would be presented in Cooper-Harper technique and listed in this section. For each question, there was a number in bracket at the end of the answer statement, this number was the score of that question if the participant chose that statement. All the scores of this questionnaire were not exposed to the participants.

The calcution of this questionnaire total score was according to the method published in Usoh et at., (2000). For each question, if the score was 5 or more than 5, that question score would be equal to 1. If the question score was less than 5, that question score would be treated as 0. As there are only 6 questions in this Slater's Questionnaire, the maximum total score that a participant can achieve is 6 (i.e. the score for each question is 5 or more than 5 = 1 x 6 questions) and the minimum total score is 0 (i.e. in the 6 questions, all of the responses were less than 5= 0 x 6 questions).

1. The overall question is

"Please rate your **sense-of-being** in the room, that was full of Tomb Raider posters, on the following scale from 1 to 7, where 7 represents your normal experience of being in a place.

I had a **sense-of-being-there** in the room full of Tomb Raider posters:
(1) - Not at all to (7) - Very much ".

Now, please answer a few multi-choice questions in relation to the above overall question:

1a. When you recall the room, that was full of Tomb Raider posters, would you rate your **sense-of-being** in that room the SAME as your normal **sense-of-being** in a physical room that you had previously visited? Yes / No

If Y 7 "VERY MUCH", If No, ask Q1b

1b. When you recall the room, that was full of Tomb Raider posters, would you rate your **sense-of-being** in that room as:

(A) much weaker than the normal **sense-of-being** in a physical room that you had previously visited, OR

(B) definite but not as strong as the normal **sense-of-being** in a physical room that you had previously visited.

Please choose (A) or (B)

If A, then choose on of the following (please read all 3 options before choosing):
(A) When I recalled about the room, that was full of Tomb Raider posters, I did NOT have a sense of **being-there** AT ALL --> (1)
(B) When I recalled about the room, that was full of Tomb Raider posters, I had a **sense-of-being-there** TO A SMALL EXTENT. --> (2)
(C) When I recalled about the room, that was full of Tomb Raider posters, I had a **sense-of-being-there** TO SOME EXTENT. --> (3)

If B, then choose one of the following (please read all 3 options before choosing):
(A) When I recalled about the room, that was full of Tomb Raider posters, I had a MODERATE **sense-of-being**-there. --> (4)
(B) When I recalled about the room, that was full of Tomb Raider posters, I had a MODERATE-TO-STRONG **sense-of-being**-there. --> (5)
(C) When I recalled about the room, that was full of Tomb Raider posters, I had a STRONG EXPERIENCE OF **being-there**. --> (6)

2. The overall question is

"To what extent were there times during the experience when the room that was full of Tomb Raider posters was the reality for you?

There were times during the experience when the room full of poster was the reality for me ... (1) At no time to (7) Almost all the time. "

Now, please answer a few multi-choice questions in relation to the above overall question:

2a. When you were experiencing the room full of Tomb Raider posters, was there a moment (however brief) that that room was **the reality** (i.e., real) for you? Y/N

If No ans. =1 (AT NO TIME). If Yes, ask Q2b

2b. When you were experiencing the room full of Tomb Raider posters, how often was the room **the reality** (i.e., was real) for you?

- (A) less than half of the time
- (B) greater or equal to half of the time

If (A) less than half of the time, then choose one of the following (please read all 3 options before choosing):
(A) When I was experiencing the room full of Tomb Raider posters, the room was RARELY **the reality** for me. (2)
(B) When I was experiencing the room full of Tomb Raider posters, the room was the **reality** for me OCCASIONALLY. (3)
(C) When I was experiencing the room full of Tomb Raider posters, the room was **the reality** for me OFTENLY BUT STILL at LESS THAN HALF OF THE TIME (4)

If '(B) greater or equal to half of the time' for Q2b, then choose one of the following (please read all 3 options before choosing):
(A) When I was experiencing the room full of Tomb Raider posters, the room was **the reality** for me at HALF OF THE TIME (5)
(B) When I was experiencing the room full of Tomb Raider posters, the room was **the reality** for me OVER HALF OF THE TIME but NOT ALL THE TIME (6)
(C) When I was experiencing the room full of Tomb Raider posters, the room was **the reality** for me ALMOST ALL THE TIME (7)

3. The overall question is "When you think back about the experience, do you think of the room, that was full of Tomb Raider posters, more as images that you saw, or more as somewhere that you visited?

The room full of posters seems to be more like ...
(1) Images that I saw to (7) Somewhere that I visited. "

Now, please answer a few multi-choice questions in relation to the above overall question:

3a. Do you agree with the following statement:
"I consider that the room, that was full of Tomb Raider posters, was JUST a series of IMAGES that I saw and DEFINITELY NOT SOMEWHERE that I visited. "

Agree / Disagree

If agree (1) Images that I saw. If disagree, ask 3b

3b. Considering the room, that was full of Tomb Raider posters. Would you agree that the room seems to be (i) SOMEWHERE that you have visited or (ii) some IMAGES that you have seen? (i) somewhere visited or (ii) images saw?

If (i), then choose one of the following (please read all 3 options before choosing):
(A) The room full of Tomb Raider posters seems to be SOMEWHERE THAT I HAVE VISITED more than SOME IMAGES THAT I HAVE SEEN. (5)
(B) The room full of Tomb Raider posters seems to be SOMEWHERE THAT I HAVE VISITED and NOT SOME IMAGES THAT I HAVE SEEN. (6)
(C) The room full of Tomb Raider posters is DEFINITELY SOMEWHERE THAT I HAVE VISITED (7)

If (ii), then choose one of the following (please read all 3 options before choosing):
(A) The room full of Tomb Raider posters seems to be SOME IMAGES THAT I HAVE SEEN and NOT SOMEWHERE THAT I HAVE VISITED (2)
(B) The room full of Tomb Raider posters seems to be SOME IMAGES THAT I HAVE SEEN MUCH more than SOMEWHERE THAT I HAVE VISITED. (3)
(C) The room full of Tomb Raider posters seems to be SOME IMAGES THAT I HAVE SEEN more than SOMEWHERE THAT I HAVE VISITED (4)

(4) The overall question is "Consider your memory of being in the room that was full of Tomb Raider posters. How similar in terms of the **structure of the memory** is this to the **structure of the memory** of other places you have been today?
Be "**structure of the memory**," consider things like the extent to which you have **a visual memory** of the room that was full of Tomb Raider posters, **whether that memory is in color**, the extent to which the memory seems **vivid (生龍活虎的;逼真;清楚的) or realistic**, its **size**, **location in your imagination**, **the extent to which it is panoramic (全景) in your imaginationand other such structural elements**

I think of the room full of posters as a place in a way similar to other places that I've been today ... (1) Not at all (7) Very much so. "

Now, please answer a few questions in relation to the above overall question

4(a) Close your eyes and remember your experience inside the room, which was full of Tomb Raider posters. Now, please CLOSE YOUR EYES until you "see" the room in your imagination. [Please try your best as any inaccuracy of your answer may delay the graduation of the experimenter, thanks]

Now, please answer the following questions (please tick the appropriate answers)
[You can close your eyes again to revisit your imagination if you have to]

4a1) Is the room in yourmemory:
__in color, __ in black & white, __both color and B/W __ cannot tell

4a2) To your best estimate, **type** in the color of the walls of the room in your memory: _____

4a3) To your best estimate, **type** in the color of the table surface of the desk inside the room in yourmemory: _____

4a4) To your best estimate, answer the following questions (you can close your eyes again to revisit the room in your imagination if needed):

what is the shape of the clock hanging on the curtain inside the room in your imagination:
__ square or __round or __don't know the shape or __ there is no clock

To your best estimate, what is the color combination of the two speakers on the desk inside the room in your imagination?
__white&back __white&blue __white&gray __others(pls specfy)

4(b) Now, please close your eyes again and remember your experience of a room (other than the room full of poster) that you have been today (e.g., the classroom of today's first lecture). Now, please CLOSE YOUR EYES until you "see" this room in your imagination. [Please try your best as any inaccuracy of your answer may delay the graduation of the experimenter, thanks]

Now, please answer the following questions (please tick the appropriate answers)
[You can close your eyes again to revisit your imagination if you have to]

4b1) What is the place that you have been today and is now imagined in your memory? Please specify _____

Is the room in yourmemory:
__in color, __ in black & white, __ cannot tell

4b2) To your best estimate, write down the color of the walls of the room in your memory: _____

4b3) If the room is a classroom, to your best estimate, write down the color of the chairs that are inside the room in your imagination: _____

If your room is NOT a classroom, please verbally describe the content of the room to the experimenter.

4b4) To your best estimate, answer the following questions (you can close your eyes again to revisit the room in your imagination if needed):

Is the clock hanging on the wall of the room in your memory:
__ square or __round or __don't know or __there is NO clock

Now, keep the imaginations (or memories) of BOTH the room full of posters AND the other room that you have visited today in your mind. Answer the following questions:

4(c) Are the **'structure of memory'** of the room full of posters and the other room that you have been today **similar** in your imagination? Yes or No
[NB: We are comparing the STRUCTURE of memory and NOT the memory itself –

if you do NOT understand this point, please ask the experimenter]

If Yes -> then choose one of the following (please read all 3 options before choosing):
[NB: We are comparing the STRUCTURE of memory and NOT the memory itself –

if you do NOT understand this point, please ask the experimenter]

(A) When I consider the colors, sizes, levels of realism, and degree of panoramic view, I think that the STRUCTURE-of-memory of the room full of posters and the STRUCTURE-of-memory of the other room that I have been today are SOMEWHAT SIMILAR. (5)

(B) When I consider the colors, sizes, levels of realism, and degree of panoramic view, I think that the STRUCTURE-of-memory of the room full of posters and the STRUCTURE-of-memory of the other room that I have been today are SIMILAR. (6)

(C) When I consider the colors, sizes, levels of realism, and degree of panoramic view, I think that the STRUCTURE-of-memory of the room full of posters and the STRUCTURE-of-memory of the other room that I have been today are VERY MUCH SIMILAR. (7)

If No, then choose one of the following (please read all 3 options before choosing):
[NB: We are comparing the STRUCTURE of memory and NOT the memory itself –

if you do NOT understand this point, please ask the experimenter]

(A) When I consider the colors, sizes, levels of realism, and degree of panoramic view, I think that the STRUCTURE-of-memory of the room full of posters and the STRUCTURE-of-memory of the other room that I have been today are DEFINITELY NOT AT ALL SIMILAR. (1)
(B) When I consider the colors, sizes, levels of realism, and degree of panoramic view, I think that the STRUCTURE-of-memory of the room full of posters and the STRUCTURE-of-memory of the other room that I have been today are NOT SIMILAR. (2)
(C) When I consider the colors, sizes, levels of realism, and degree of panoramic view, I think that the STRUCTURE-of-memory of the room full of posters and the STRUCTURE-of-memory of the other room that I have been today are WEAKLY SIMILAR. (3)
(D) When I consider the colors, sizes, levels of realism, and degree of panoramic view, I think that the STRUCTURE-of-memory of the room full of posters and the STRUCTURE-of-memory of the other room that I have been today are SOMEWHAT SIMILAR (4)

5. The overall question is "During the time of the experience, which was strongest on the whole, your sense of being in the room, that was full of Tomb Raider posters, or of being elsewhere?

I has a stronger sense of ...
(1) being elsewhere to (7) being in the room full of posters "

Now, please answer a few multi-choice questions in relation to the above overall question

5a. Do you agree with the following statement:
"During the whole period of experiencing the room full of posters, I was CONSTANTLY aware and ALWAYS had a stronger **sense-of-being** elsewhere rather than **being** inside that room." Agree / Disagree

If Agree -> (1) Being elsewhere If Disagree, ask Q5b

5b. On the whole, during the time of experiencing the room full of posters, which was STRONGER? the **sense-of-being** in that room? or the **sense-of-being** elsewhere?

If 'that room', then choose one of the following (please read all 3 options before choosing):
(A) During the time of experiencing the room full of posters, I had a SLIGHTLY STRONGER **sense-of-being** in that room than **being** elsewhere. (5)
(B) During the time of experiencing the room full of posters, I had a MODERATELY STRONGER **sense-of-being** in that room than **being** elsewhere. (6)
(C) During the time of experiencing the room full of posters, I ALWAYS had a MUCH STRONGER **sense-of-being** in that room than **being** elsewhere (7)

If 'elsewhere', then choose one of the following (please read all 3 options before choosing):
(A) During the time of experiencing the room full of posters, I had a MODERATELY STRONGER **sense-of-being** elsewhere than **being** that room. (2)
(B) During the time of experiencing the room full of posters, I had a SLIGHTLY STRONGER **sense-of-being** elsewhere than **being** that room. (3)
(c) During the time of experiencing the room full of posters, the **sense-of-being** elsewhere and the **sense-of-being** in that room are SIMILAR. (4)

6. The overall question is "During the time of the experience, did you often think to yourself that you were actually in the room that was full of Tomb Raider posters?

During the experience I often thought that I was really inside the room full of posters ... (1) Not very often to (7) Very much so. "

Now, please answer a few multi-choice questions in relation to the above overall question.

6a. During the time of experiencing the room full of posters, how often did you think that you were actually in that room?

(i) Not very often (ii) sometimes (iii) very often

If (i), (1) Not very often.

If (iii), then choose one of the following (please read all 3 options before choosing):
(A) During the time of experiencing the room full of posters, I OFTEN thought that I was really in that room. (5)
(B) During the time of experiencing the room full of posters, I VERY OFTEN thought that I was really in that room. (6)
(C) During the time of experiencing the room full of posters, I ALWAYS thought that I was really in that room. (7)

If (ii), then choose one of the following (please read all 3 options before choosing):
(A) During the time of experiencing the room full of posters, I SELDOMLY thought that I was really in that room. (2)
(B) During the time of experiencing the room full of posters, I SOMETIMES thought that I was really in that room. (3)
(C) During the time of experiencing the room full of posters, I OFTEN thought that I was really in that room. (4)

Appendix 3.1 Virtual Environment Performance Assessment Battery (VEPAB)

Virtual Environment Performance Assessment Battery (VEPAB) was developed by Lampton and his colleagues in 1996. The VEPAB provided tasks which allow participants to perceive, move through and interact with objects in virtual environments (VEs). The tasks proposed in VEPAB were performance sensitive to individual differences and input control devices. The proposed tasks in VEPAB covered the area of vision, locomotion, tracking, object manipulation, and reaction time tasks performed in VEs and were listed in below table (Table A3.1a) which was extracted from the publication in 1996 (pp.148).

Table A3.1a The VEPAB original tasks

Task category	Task name	Task description
Vision	Acuity	Read letters in a Snellen chart
	Color	Detect colors in Ishihara plates
	Object recognition	Identify an object (a human figure) at the end of a 40ft hallway
	Size estimation	Estimate the height of a human figure at the end of a 40ft hallway
	Distance estimation	Indicate when the image of a human figure, moving toward

		the viewer from an initial distance of 40, 30, 20, 10, 5, and 2.5 ft away
	Search	Detect a target moving about the walls, floor, or ceiling of a room
Locomotion (walking)	Straight-away	Move down a straight corridor to a circle on the floor, turn around, and return to the starting point
	Backup	Move down a straight corridor to a circle on the floor, then move backward to the starting point
	Turns	Move through a corridor formed by 10 alternating left and right 90 degrees turns
	Figure-8	Move around a figure-8 shaped corridor
	Doorways	Move through a series of rooms connected by doorways that are offset

		so that a curved course must be followed
Locomotion (flying)	Windows	Like Doorways, except that some of the openings are elevated, so that vertical, as well as horizontal, movement is required
	Elevator	Move forward through a structure while going over or under a series of vertical obstacles
Manipulation	Slide	"Grasp" a control bar and move t horizontally to a marked location
	Dial	"Grasp" a dial and rotate it to an indicated orientation
	Bins	"Grasp" a ball located in a vertical rack of open containers, pull it our of the original bin, and push it into a target bin
Tracking	Head control, stationary target	Use head movements to move a cursor,

		centered in the viewing device, onto a stationary target
	Head control, moving target	Use head movements to move a cursor, centered in the viewing device, onto a target moving in a straight line
	Device control, stationary target	Use a control device to move a cursor onto a stationary target
	Device control, moving target	Use a control device to move a cursor onto a target moving in a straight line
Reaction time	Simple	Indicate when an "X" pops into view
	Choice	Indicate in which of four boxes an "X" has appeared

Appendix 3.2 The Simulator Sickness Questionnaire (SSQ) used in this study

Simulator Sickness Questionnaire (SSQ) was developed by Kennedy, et al, (1993). SSQ contains 29 symptoms investigating simulator sickness with a 4-point rating scale: none, slight, moderate and severe. The whole SSQ actually contains of 2 set of questionnaires, both of them list out the same symptoms. One was used before exposed to the environment which is called Pre-SSQ and another was used after exposed to the environment which is called Post-SSQ. The symptoms are divided into 3 clusters, and a Total Score. The 3 clusters are Nausea, Oculomotor and Discomfort. The symptoms included in each cluster are:

Nausea: General discomfort, increased salivation, sweating, nausea, difficulty concentrating, stomach awareness and burping

Oculomotor: General discomfort, fatigue, headache, eyestrain, difficulty focusing, difficulty concentrating and blurred vision

Discomfort: Difficulty focusing, nausea, fullness of the head, blurred vision, dizziness eyes open, dizziness eyes close and vertigo

The original questionnaire was in English only. In this study, there were Chinese translations of the symptoms listed beside the English names to ensure that participants had full understanding of the questionnaire.

The method of calculating the SSQ clusters and total score is shown as the table below. The score represents the degree of the sickness that the participants felt.

Clusters	**Symptoms**	**Computation**
Nausea (N)	1+8b+9+10+11+20+25=X	N=X*9.54
Oculomotor(O)	1+2+5+6+7+11+14=Y	O=Y*7.58
Disorientation(D)	7+10+13+14+15a+15b+16=Z	D=Z*13.92
Total Score (TS)	X+Y+Z	TS=(X+Y+Z)*3.74

SYMPTOM CHECKLIST (Pre-exposure)
confidential

Pre-exposure instructions: please fill in this questionnaire. Circle below if any of the symptoms apply to you now. You will be asked to fill this again after the experiment.

一般不適	1. General discomfort	None	Slight Moderate Severe
疲倦	2. Fatigue	None	Slight Moderate Severe
沉悶	3. Boredom	None	Slight Moderate Severe
想睡	4. Drowsiness	None	Slight Moderate Severe
頭痛	5. Headache	None	Slight Moderate Severe
眼痛	6. Eyestrain	None	Slight Moderate Severe
很難集中視力	7. Difficulty focusing	None	Slight Moderate Severe
口水分秘增加	8. Salivation increase	None	Slight Moderate Severe
口水分秘減少	Salivation decrease	None	Slight Moderate Severe
出汗	9. Sweating	None	Slight Moderate Severe
作嘔	10. Nausea	None	Slight Moderate Severe
很難集中精神	11. Difficulty concentrating	None	Slight Moderate Severe
精神的壓抑	12. Mental depression	No	Yes (Slight Moderate Severe)
頭脹	13. "Fullness of the head"	No	Yes (Slight Moderate Severe)
視野模糊	14. Blurred vision	No	Yes (Slight Moderate Severe)
眼花 (開)	15. Dizziness eyes open	No	Yes (Slight Moderate Severe)
眼花 (合)	Dizziness eyes close	No	Yes (Slight Moderate Severe)
眩暈	16. Vertigo	No	Yes (Slight Moderate Severe)
幻覺	17. Visual flashbacks*	No	Yes (Slight Moderate Severe)
昏厥	18. Faintness	No	Yes (Slight Moderate Severe)
呼吸異樣	19. Aware of breathing	No	Yes (Slight Moderate Severe)
胃感覺異樣	20. Stomach awareness	No	Yes (Slight Moderate Severe)
沒有胃口	21. Loss of appetite	No	Yes (Slight Moderate Severe)
胃口增加	22. Increased appetite	No	Yes (Slight Moderate Severe)
想去洗手間	23. Desire to move bowels	No	Yes (Slight Moderate Severe)
迷惘	24. Confusion	No	Yes (Slight Moderate Severe)
打嗝	25. Burping	No	Yes (Slight Moderate Severe)
嘔吐	26. Vomiting	No	Yes (Slight Moderate Severe)
其他	27. Other	No	Yes (Slight Moderate Severe)

SYMPTOM CHECKLIST (Post-exposure)

confidential

Post-exposure instruction: please fill in this questionnaire once more. Circle below if any of the symptoms apply to you now.

一般不適	1. General discomfort	None	Slight	Moderate Severe
疲倦	2. Fatigue	None	Slight	Moderate Severe
沉悶	3. Boredom	None	Slight	Moderate Severe
想睡	4. Drowsiness	None	Slight	Moderate Severe
頭痛	5. Headache	None	Slight	Moderate Severe
眼痛	6. Eyestrain	None	Slight	Moderate Severe
很難集中視力	7. Difficulty focusing	None	Slight	Moderate Severe
口水分秘增加	8. Salivation increase	None	Slight	Moderate Severe
口水分秘減少	Salivation decrease	None	Slight	Moderate Severe
出汗	9. Sweating	None	Slight	Moderate Severe
作嘔	10. Nausea	None	Slight	Moderate Severe
很難集中精神	11. Difficulty concentrating	None	Slight	Moderate Severe
精神的壓抑	12. Mental depression	No	Yes (Slight	Moderate Severe)
頭脹	13. "Fullness of the head"	No	Yes (Slight	Moderate Severe)
視野模糊	14. Blurred vision	No	Yes (Slight	Moderate Severe)
眼花 (開)	15. Dizziness eyes open	No	Yes (Slight	Moderate Severe)
眼花 (合)	Dizziness eyes close	No	Yes (Slight	Moderate Severe)
眩暈	16. Vertigo	No	Yes (Slight	Moderate Severe)
幻覺	17. Visual flashbacks*	No	Yes (Slight	Moderate Severe)
昏厥	18. Faintness	No	Yes (Slight	Moderate Severe)
呼吸異樣	19. Aware of breathing	No	Yes (Slight	Moderate Severe)
胃感覺異樣	20. Stomach awareness	No	Yes (Slight	Moderate Severe)
沒有胃口	21. Loss of appetite	No	Yes (Slight	Moderate Severe)
胃口增加	22. Increased appetite	No	Yes (Slight	Moderate Severe)
想去洗手間	23. Desire to move bowels	No	Yes (Slight	Moderate Severe)
迷惘	24. Confusion	No	Yes (Slight	Moderate Severe)
打嗝	25. Burping	No	Yes (Slight	Moderate Severe)
嘔吐	26. Vomiting	No	Yes (Slight	Moderate Severe)
其他	27. Other	No	Yes (Slight	Moderate Severe)

Appendix 4.1 The immersive tendency questionnaire (ITQ) used in this study

The Immersive Tendency Questionnaire (Witmer and Singer, 1996) was developed to " identify real world behaviours and tendencies that may predict how much presence individuals will or can experience presence in a remote or artificial environment." Its reliability is 0.81 that is in the reasonable level (Witmer and Singer, 1996). Totally there are 34 questions (all in a 7-point scale) and 19 of them are counted to the Total Score. The higher the Total Score, the higher the tendency to immerse to the environment is.

Calculation of the Total Score: summation of Q1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

In order to let the participants understand the questions easily, some Chinese translations and examples are also added in blankets. The meaning of the original questions are not changed and so as the words.

Immersive Tendency Questionnaire

Indicate your preferred answer by marking an "X" in the **MIDDLE** of the appropriate box of the 7-point scale. Please consider the entire scale when making your responses, as the intermediate levels may apply. For example, if your response is once or twice, the second box from the left should be marked. If your response is many times but not extremely often, then the sixth (or second box from the right) should be marked.

1. Do you easily become deeply involved in movies or TV dramas?

Never Occasionally Often

2. Do you ever become so involved in a television program or book that people have problems getting your attention?

Never Occasionally Often

3. How mentally alert do you feel at the present time?

Not Alert Moderately Fully Alert

4. Do you ever become so involved in a movie that you are not aware of things happening around you?

Never Occasionally Often

5. How frequently do you find yourself closely identifying with the characters in a story line? (你是否常常對故事人物產生認同感？)

Never Occasionally Often

6. Do you ever become so involved in a video game that it is as if you are inside the game rather than moving a joystick and watching the screen?

Never Occasionally Often

7. What kind of leisure books do you read <u>most frequently</u>? (CIRCLE ONE ITEM ONLY!)

Spy novels	Fantasies	Science fiction
AdventureRomance novels	Historical novels	
Westerns(西部小說)	Mysteries (懸 疑 小 說)	Other fiction
Biographies (傳 記)	Autobiographies (自 傳)	Other non-fiction

8. How physically fit do you feel today?

Not Fit Moderately Fit Extremely Fit

9. How good are you at blocking out external distractions when you are involved in something?

Not Very Good Somewhat Good Very Good

10. When watching sports, do you ever become so involved in the game that you react as if you were one of the players?

Never Occasionally Often

11. Do you ever become so involved in a daydream that you are not aware of things happening around you?

Never Occasionally Often

12. Do you ever have dreams that are so real that you feel disoriented (不 知 自 己 身 在 何 處) when you awake?

Never Occasionally Often

13. When playing sports, do you become so involved in the game that you lose track of time (失 去 時 間 觀 念)?

Never Occasionally Often

14. How well do you concentrate on enjoyable activities?

Not at all Moderately well Very Well

15. How often do you play arcade (打 機) or video games? (OFTEN should be taken to mean every day or every two days, on average.)

Never Occasionally Often

16. Have you ever gotten excited during a chase or fight scene on TV or in the movies?

Never Occasionally Often

17. Have you gotten scared by something happening on a TV show or in a movie?

Never Occasionally Often

18. Have you ever remained apprehensive (憂 慮) or fearful long after watching a scary movie?

Never Occasionally Often

19. Do you ever become so involved in doing something that you lose all track of time (失 去 時 間 觀 念)?

Never Occasionally Often

20. On average, how many books do you read for enjoyment in a month?

None One Two Three Four Five More

21. Do you ever get involved in projects or tasks, to the exclusion of other activities?

Never Occasionally Often

22. How easily can you switch attention from the activity in which you are currently involved to a **new and completely different** activity?

Not so Easily Fairly Easily Quite Easily

23. How often do you try new restaurants or new foods when presented with the opportunity?

Never Occasionally Frequently

24. How frequently do you volunteer to serve on committees, planning groups, or other civic or social groups?

Never Sometimes Frequently

25. How often do you try new things or seek out new experiences?

Never Occasionally Often

26. Given the opportunity, would you travel to a country with a **different culture** and a **different language** (i.e. you don't know the culture and the language)?

Never Maybe Absolutely

27. Do you go on carnival rides (嘉 年 華 會 巡 遊) or participate in other leisure activities (horse back riding, bungee jumping, snow skiing, water sports) for the excitement of thrills that they provide?

Never Occasionally Often

28. How well do you concentrate on disagreeable tasks (i.e. tasks that you dislike)?

Not at all Moderately Well Very Well

29. How often do you play games on computers?

Not at all Occasionally Frequently

30. How many different video, computer, or arcade games have you become reasonably good at playing?

None One Two Three Four Five More

31. Have you ever felt completely caught up in an experience(神遊太虛), aware of everything going on (inside the experience) and completely open to all of it (ie refers to events in the experience)?

Never Occasionally Frequently

32. Have you ever felt completely focused on something, so wrapped up in that one activity that nothing could distract you?

Never Occasionally Frequently

33. How frequently do you get emotionally involved (angry, sad, or happy) in news stories that you see, read, or hear?

Never Occasionally Often

34. Are you easily distracted when involved in an activity or working on a task?

Never Occasionally Often

Appendix 4.2 The excitement questionnaire

The excitement questionnaire was developed to measure the level of excitement that participants felt towards (1) overall experience, (2) task and navigation and (3) the virtual environment. All the questions were in Likert scale rating 1 to 7 with neutral point (middle position) provided. The total score for each section were calculated by adding all the score value within that section directly.

THE EXCITEMENT QUESTIONNAIRE

Questions 1 to 6 are about your **overall experience** of the virtual reality exposure. (please put a tick in the appropriate box).

Please feel free to choose Strongly-disagree

Q1) The experience with this virtual reality exposure completely meet my expectation.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

☐ ☐ ☐ avoid ☐ ☐ ☐

Q2) I am very pleased with my overall experience of this virtual reality exposure.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

☐ ☐ ☐ avoid ☐ ☐ ☐

Q3) Given the opportunity, I would like to repeat this virtual reality exposure again.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

☐ ☐ ☐ avoid ☐ ☐ ☐

Q4) The experience with this virtual reality exposure makes me excited.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

☐ ☐ ☐ avoid ☐ ☐ ☐

Q5) I enjoy my experience of this virtual reality exposure very much.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

☐ ☐ ☐ avoid ☐ ☐ ☐

Q6) I am very impressed by this virtual reality exposure.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

☐ ☐ ☐ avoid ☐ ☐ ☐

We are asking you to separate your overall comments to (i) comments specific to the task and navigation, and (ii) comments specific to the virtual environment (VE).

Questions 7 to 12 are about your comments on the task and navigation ONLY. (please put a tick in the appropriate box).

Please feel free to choose Strongly-disagree

Q7) Regardless of whether the VE is good or bad, the tasks and navigation during this virtual reality exposure completely meet my expectation.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Q8) Regardless of whether the VE is good or bad, I am very pleased with the task and navigation during this virtual reality exposure.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Q9) There is something in the tasks alone that really makes me excited.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Q10) There is something in the navigation alone that really makes me excited.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Q11) Regardless of whether the VE is good or bad, I enjoy my experience of the tasks and navigation during the virtual reality exposure very much.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Q12) Regardless of whether the VE is good or bad, I am very impressed by the tasks and navigation during the virtual reality exposure.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Questions 13 to 18 are about your comments on the virtual environment ONLY. (please put a tick in the appropriate box).

Please feel free to choose Strongly-disagree

Q13) Regardless of whether the tasks and navigation are good or bad, the virtual environment completely meet my expectation.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Q14) Regardless of whether the tasks and navigation are good or bad, I am very pleased with the virtual environment.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Q15) If a game developer develops a virtual reality game using this virtual environment, I would be interested in playing the game.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Q16) There is something inside the virtual environment alone that really makes me excited.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Q17) Regardless of whether the tasks and navigation are good or bad, I enjoy the virtual environment very much.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Q18) Regardless of whether the tasks and navigation are good or bad, I am very impressed by the virtual environment.

Strongly-agree Agree Slightly-agree Neutral Slightly-disagree Disagree Strongly-disagree

			avoid			

Q19) What can we improve the virtual reality experience in order to increase your excitement and pleasure [any suggestions are welcome! Please give us some suggestions].

_____

_____

_____

_____

_____

_____

_____

_____

-- Thank you very much for your time --

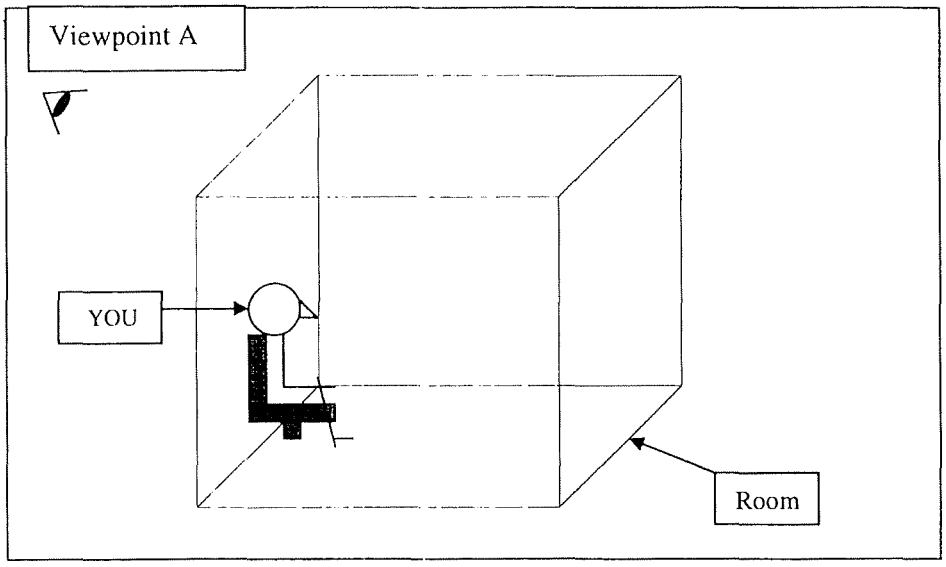
Appendix 4.3 Perspective drawing

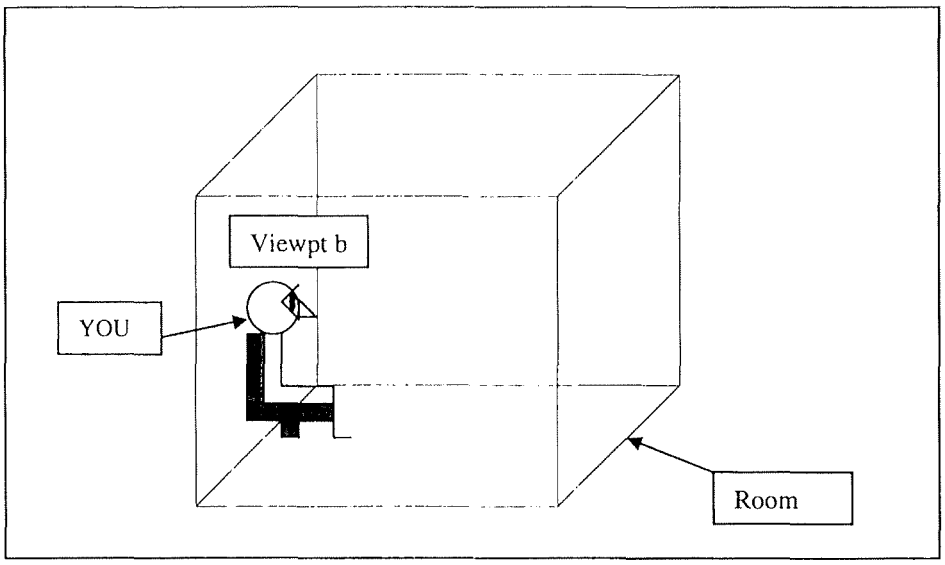
The participants were requested to draw 4 pictures in order to finish the whole perspective drawing. These 4 pictures included one was drawing a model house and the other three were completed by what they could remember from the experimental environments that they have visited in three different viewpoints. The purpose of introducing the perspective drawing was to investigate how the participants perceived the environments and the way that they remembered the objects within the environments. The first picture which was the model house and this was used to check the drawing abilities of the participants and used as a reference.

1. Please draw out the temple model which is placed in front of you. You can only view it from where you are sitting and during the observation or drawing, PLEASE DO NOT TOUCH THE TEMPLE MODEL. There is NO TIME LIMIT on this, BUT please do DRAW AS BEST AS YOU CAN.

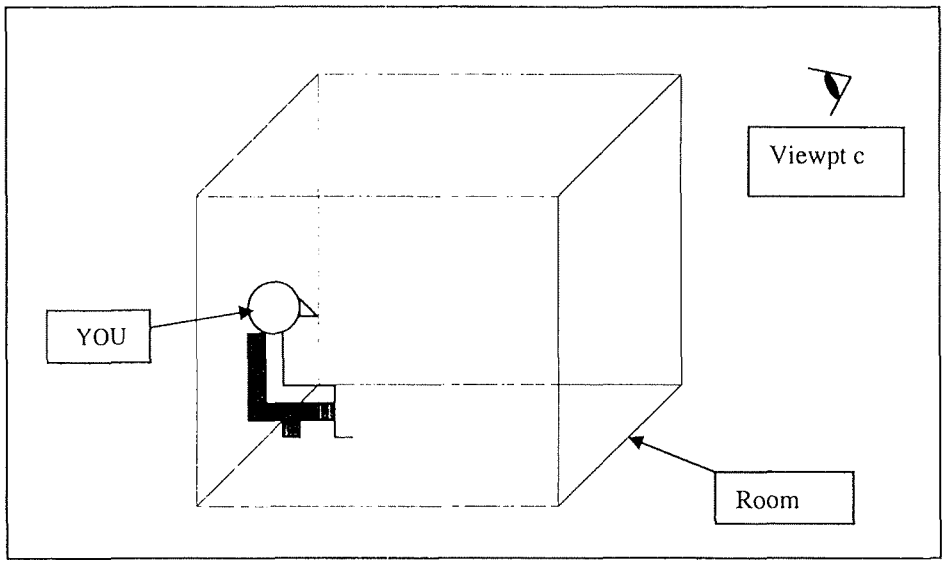
2. Refer to your memory and draw out the room which is full of Tomb Raider posters in according to the stated viewpoint.

2(a)





2(b) Picture from Viewpt b



2(c) Picture from Viewpt c

Appendix 5.1 The 18 questions selected from the Presence questionnaire (PQ) in which the extreme ratings should be selected by the participants in Experiment 1 exposed to the real environment condition without restriction on field-of-view but with head-mounted weight (RE_weight)

There are totally 32 questions in the Presence Questionnaire (PQ) and via the logical deduction, 18 questions were selected. For these 18 questions, we expect that the participants exposed to the real environment without restriction on field-of-view but with head-mounted weight (RE-weight) in Experiment 1 should have selected the extreme ratings which means either a rating of '1' or '7' was selected.

Table A5.1 lists these selected 18 questions with explanations on why they were chosen, the expected ratings of these questions, the actual average ratings of these questions collected from the RE_weight condition of Experiment 1, and the possible reasons for the differences between the collected ratings and the expected ratings.

Table A5.1 The selected 18 questions in which extreme ratings should have been selected in the RE_weight condition. The extreme ratings in this study were 'completely' and 'not-at-all' (i.e. ratings of '1' and '7')

The selected questions	*Expected ratings of the corresponding question in the RE_weight condition*	*The reason to support our expectation for the participants to select extreme ratings*	*The actual rating collected in RE-weight condition of Experiment 1*	*Possible reasons for the differences between the expected and collected ratings (as collected by comments from the participants)*
1. How much were you able to control events? Ratings: 1	2	3	4	5	6	7 Meanings: Not at all			Somewhat			completely	Rating-7 : completely	There were no restrictions on hand and head movements which can affect on the tasks that the participants needed to perform	Mean value = 4.83 s.d.= 1.27	Participants misunderstood the meaning of the question as "How much were you able to control whether you would follow the experimenter's decisions?"
2. How responsive was the environment to actions that you initiated (or performed)? Ratings: 1	2	3	4	5	6	7 Meanings: Not responsive			Moderately responsive			Completely responsive	Rating-7: completely responsive	As the environment was a real environment, the responsiveness of the action was the same as in real world.	Mean value = 4.75 S.D. =1.67	Participants were confused by the meaning of the question.

<table>
<tr><th>The selected questions</th><th>Expected ratings of the corresponding question in the RE_weight condition</th><th>The reason to support our expectation for the participants to select extreme ratings</th><th>The actual rating collected in RE-weight condition of Experiment 1</th><th>Possible reasons for the differences between the expected and collected ratings (as collected by comments from the participants)</th></tr>
<tr><td>3. How natural did your interactions with the environment seem?
<table>
<tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>meanings</td><td>Extremely artificial</td><td></td><td></td><td>Borderline</td><td></td><td></td><td>Completely natural</td></tr>
</table></td><td>Rating-7: Completely natural</td><td>RE_weight is a real environment and the interactions within that environment was as natural as in a real world. Although participants had to wear a headset of 1 kg weighted, that weight did not obstruct the field-of-view and certainly did not interfere with any manual operations.</td><td>Mean value = 3.75
S.D.=1.22</td><td>The headset weight affected the head movements or some interpreted that participants' interactions with the environment, even though that is real, would not be natural because they were participating an experiment.</td></tr>
<tr><td>6. How natural was the mechanism which controlled movement through the experimental environment?
<table>
<tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>Meanings</td><td>Extremely artificial</td><td></td><td></td><td>Borderline</td><td></td><td></td><td>Completely natural</td></tr>
</table></td><td>Rating-7: Completely natural</td><td>The mechanism that the participants could use to controlled movement through the RE_weight were their very own hands and they were believed to be the most natural mechanism that the participants ever experienced to.</td><td>Mean value = 4.25
S.D. = 0.96</td><td>Participants mixed up the feelings of uncomfortable with the unnatural. As participants wore gloves all the way during the experiments and the cables which were attached to the gloves caused uncomfortable sometimes during the experiment.</td></tr>
</table>

The selected questions	*Expected ratings of the corresponding question in the RE_weight condition*	*The reason to support our expectation for the participants to select extreme ratings*	*The actual rating collected in RE-weight condition of Experiment 1*	*Possible reasons for the differences between the expected and collected ratings (as collected by comments from the participants)*
8. How much did your experiences in the experimental environment seem consistent with your real world experiences? Ratings: 1	2	3	4	5	6	7 Meanings: Not consistent			Moderately consistent			Very consistent	Rating-7: very consistent	The RE_weight is a real environment, therefore the experiences of the participants in the RE_weight should be consistent with the real world.	Mean value = 4.83 S.D. = 1.70	Participants were confused with the meaning of the question
9. Were you able to anticipate what would happen next in response to the actions that you performed? Ratings: 1	2	3	4	5	6	7 Meanings: Not at all			Somewhat			Completely	Rating – 7: completely	As the participants can anticipate what can happen next to their actions in the real world, they could also do the same in RE_weight which is also a real environment. The headset should not affect them on this.	Mean value = 4.67 S.D. = 1.50	Same as above
10. How completely were you able to actively survey or search the environment using vision? Ratings: 1	2	3	4	5	6	7 Meanings: Not at all			Somewhat			Completely	Rating -7: Completely	Consider that the participants can completely observe the real world using their eyes, they should be able to observe the	Mean value = 4.47 S.D. = 1.15	Participants misunderstood the question as the freedom of doing active visual search by following their own mind but without

The selected questions	*Expected ratings of the corresponding question in the RE_weight condition*	*The reason to support our expectation for the participants to select extreme ratings*	*The actual rating collected in RE-weight condition of Experiment 1*	*Possible reasons for the differences between the expected and collected ratings (as collected by comments from the participants)*
		RE_weight environment completely. Participants in the RE_weight did not have any restricitions on their visions at all.		searching the stated targets at all.
11. How well could you identify sounds? Ratings: 1 2 3 4 5 6 7 Meanings: Not at all — Somewhat — Completely	Rating-7: completely	The sound was either the music or instructions that were played via the real physical speakers or the sound that the participants made while performing the tasks in RE_weight environment. As the participants had normal hearing ability, they should be able to identify the sounds in RE_weight and the headset should not have any affect on the hearing ability at all.	Mean value =6.08 S.D. = 1.08	Some of the participants were avoiding to choose the answer of "completely" even if they did.

<table>
<tr><th>The selected questions</th><th>Expected ratings of the corresponding question in the RE_weight condition</th><th>The reason to support our expectation for the participants to select extreme ratings</th><th>The actual rating collected in RE-weight condition of Experiment 1</th><th>Possible reasons for the differences between the expected and collected ratings (as collected by comments from the participants)</th></tr>
<tr><td>12. How well could you localize sounds?
<table><tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>Meanings</td><td>Not at all</td><td></td><td></td><td>Somewhat</td><td></td><td></td><td>Completely</td></tr></table></td><td>Rating-7: completely</td><td>Same as above</td><td>Mean value = 6.00
S.D. = 1.13</td><td>Same as above</td></tr>
<tr><td>13. How well could you actively survey or search the experimental environment using touch?
<table><tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>Meanings</td><td>Not at all</td><td></td><td></td><td>Somewhat</td><td></td><td></td><td>Completely</td></tr></table></td><td>Rating-7: completely</td><td>Participants could use their hands to touch and manipulate objects as the way they do in the real world.</td><td>Mean value = 5.33
S.D. =1.15</td><td>Some participants interpreted the questions as “ The chances of you can actively survey or search the experimental environment using touch in your own will.”.</td></tr>
<tr><td>15. How closely were you able to examine objects?
<table><tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>meanings</td><td>Not at all</td><td></td><td></td><td>Pretty closely</td><td></td><td></td><td>Very closely</td></tr></table></td><td>Rating-7: very closely</td><td>As the participants can observe or examine objects closely in the real world, participants could also apply their skills to examine objects very closely in the RE_weight. As RE_weight ia a real environment and</td><td>Mean value = 4.33
S.D. = 1.33</td><td>Participants did not remember whether they actually had tried to closely examine objects within the environment or not.</td></tr>
</table>

<table>
<tr><th>The selected questions</th><th>Expected ratings of the corresponding question in the RE_weight condition</th><th>The reason to support our expectation for the participants to select extreme ratings</th><th>The actual rating collected in RE-weight condition of Experiment 1</th><th>Possible reasons for the differences between the expected and collected ratings (as collected by comments from the participants)</th></tr>
<tr><td></td><td></td><td>participants can closely observed the objects by using their eyes.</td><td></td><td></td></tr>
<tr><td>16. How well could you examine objects from multiple viewpoints?
<table><tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>meanings</td><td>Not at all</td><td></td><td></td><td>Somewhat</td><td></td><td></td><td>extensively</td></tr></table></td><td>Rating-7: extensively</td><td>The headset that the participants wore in the RE_weight did not restrict the participants' abilities to observe the objects from multiple viewpoints at all. In addition, based on a logical assumption that all the participants can examine objects from multiple viewpoints, they could also do this in the RE_weight environment.</td><td>Mean value = 4.83
S.D. = 1.03</td><td>There were participants claimed that they did not try that in the environments and some of the participants did not fully understand the meaning of the question.</td></tr>
</table>

<table>
<tr><th>The selected questions</th><th>Expected ratings of the corresponding question in the RE_weight condition</th><th>The reason to support our expectation for the participants to select extreme ratings</th><th>The actual rating collected in RE-weight condition of Experiment 1</th><th>Possible reasons for the differences between the expected and collected ratings (as collected by comments from the participants)</th></tr>
<tr><td>17. How well could you move or manipulate objects in the experimental environment?
<table><tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>meanings</td><td>Not at all</td><td></td><td></td><td>Somewhat</td><td></td><td></td><td>extensively</td></tr></table></td><td>Rating -7: extensively</td><td>Participants used their own hands to move or manipulate the objects in the experimental environments. The age range of the participants in this experiment is from 18 to 25, which means they had at least 18 years of experiences on manipulating objects. Based on this, we believe the participants could move the objects very well in this environment.</td><td>Mean value = 4.75
S.D. = 1.13</td><td>Participants were reluctant to give out the responses as “extensively”</td></tr>
<tr><td>19. How much delay did you experience between your actions and expected outcomes?
<table><tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>meanings</td><td>No delays</td><td></td><td></td><td>Moderate delays</td><td></td><td></td><td>Long delays</td></tr></table></td><td>Rating-1: no delays</td><td>The time delay here is refer to the delay from the action started to the time when the action is visualised. Assume that there was no time delay occurred in the real</td><td>Mean value = 4.83
S.D. = 1.27</td><td>Participants considered this question was about the thinking time which spent on planning the next actions.</td></tr>
</table>

<table>
<tr><th>The selected questions</th><th>Expected ratings of the corresponding question in the RE_weight condition</th><th>The reason to support our expectation for the participants to select extreme ratings</th><th>The actual rating collected in RE-weight condition of Experiment 1</th><th>Possible reasons for the differences between the expected and collected ratings (as collected by comments from the participants)</th></tr>
<tr><td></td><td></td><td>world was noticeable to the participants, there should be also no time delay noticeable in the RE_weight environment.</td><td></td><td></td></tr>
<tr><td>20. How quickly did you adjust to virtual environment experience?
<table><tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>meanings</td><td>Not at allt</td><td></td><td></td><td>Slowly</td><td></td><td></td><td>Less than 1 min.</td></tr></table></td><td>Rating – 7: less than a minute</td><td>The main difference between RE_weight environment and the real world was the existence of the headset weight. Therefore adapting the RE_weight environment was not considered as a difficult thing to be accomplished.</td><td>Mean value = 4.92
S.D. =1.62</td><td>Participants were reluctant to choose the answers of “less than a minute”</td></tr>
<tr><td>22. How much did the restriction of vision or visual display quality interfere or distract you from performing assigned tasks or required activities?
<table><tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>meanings</td><td>Not at all</td><td></td><td></td><td>Interfered somewhat</td><td></td><td></td><td>Prevented task performance</td></tr></table></td><td>Rating – 1: Not at all</td><td>The headset added on the participant’s head in the RE_weight environment did not block the visual ability of the participant at</td><td>Mean value =4.42
S. D.=1.00</td><td>Participants misunderstood the meaning of the “restriction of vision or visual display quality”. They considered the uncomfortable of</td></tr>
</table>

<table>
<tr><th>The selected questions</th><th>Expected ratings of the corresponding question in the RE_weight condition</th><th>The reason to support our expectation for the participants to select extreme ratings</th><th>The actual rating collected in RE-weight condition of Experiment 1</th><th>Possible reasons for the differences between the expected and collected ratings (as collected by comments from the participants)</th></tr>
<tr><td></td><td></td><td>all.</td><td></td><td>wearing the headset as part of the visual display quality interference.</td></tr>
<tr><td>23. How much did the control devices interfere with the performance of assigned tasks or with other activities?
<table><tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>meanings</td><td>Not at allt</td><td></td><td></td><td>Interfered somewhat</td><td></td><td></td><td>Interfered greatly</td></tr></table></td><td>Rating – 1: Not at all</td><td>The headset used in the RE_weight did not interfere the participants to perform the visual search task nor object manipulations.</td><td>Mean value = 4.5
S.D. = 1.09</td><td>Participants counted uncomfortable due to the headset as part of the interferences.</td></tr>
<tr><td>29. How easily was it to identify objects through physical interaction; like touching an object, walking over a surface, or bumping into a wall or object?
<table><tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>meanings</td><td>Impossible</td><td></td><td></td><td>Moderately difficult</td><td></td><td></td><td>Very Easy</td></tr></table></td><td>Rating -7: very easy</td><td>The participants had thorough experience on using their hands to identify objects, therefore when doing the same thing in the RE_weight should be an easy task.</td><td>Mean value = 4.83
S. D. = 1.53</td><td>The participants were reluctant to choose the responses of “very easy”</td></tr>
<tr><td>31. How easily did you adjust to the control device used to interact with the experimental environment?
<table><tr><td>Ratings</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>meanings</td><td>Difficult</td><td></td><td></td><td>Moderate</td><td></td><td></td><td>Easily</td></tr></table></td><td>Rating – 7: easily</td><td>The participants used their hands as the control device to interact with the RE_weight environment. The experience of using</td><td>Mean value = 4.92
S.D. = 1.62</td><td>Same as above</td></tr>
</table>

The selected questions	*Expected ratings of the corresponding question in the RE_weight condition*	*The reason to support our expectation for the participants to select extreme ratings*	*The actual rating collected in RE-weight condition of Experiment 1*	*Possible reasons for the differences between the expected and collected ratings (as collected by comments from the participants)*
		their own hands should be enough for them to handle the objects or interact with the RE_weight.		