Observing Effects of Attention on Presence with fMRI

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ABSTRACT

Presence is one of the goals of many virtual reality systems. Historically, in the context of virtual reality, the concept of presence has been associated much with spatial perception (bottom up process) as its informal definition of "feeling of being there" suggests. However, recent studies in presence have challenged this view and attempted to widen the concept to include psychological immersion, thus linking more high level elements (processed in a top down fashion) to presence such as story and plots, flow, attention and focus, identification with the characters, emotion, etc. In this paper, we experimentally studied the relationship between two content elements, each representing the two axis of the presence dichotomy, perceptual cues for spatial presence and sustained attention for (psychological) immersion. Our belief was that spatial perception or presence and a top down processed concept such as voluntary attention have only a very weak relationship, thus our experimental hypothesis was that sustained attention would positively affect spatial presence in a virtual environment with impoverished perceptual cues, but have no effect in an environment rich in them. In order to confirm the existence of the sustained attention in the experiment, fMRI of the subjects were taken and analyzed as well. The experimental results showed that that attention had no effect on spatial presence, even in the environment with impoverished spatial cues.

Categories and Subject Descriptors

I.3.7 [**Computer Graphics**]: Three-Dimensional Graphics and Realism – *virtual reality*; J.4 [**Social and Behavioral Sciences**]: Psychology

General Terms

Human Factors

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Keywords

Virtual Reality, Presence, fMRI, Attention

1. INTRODUCTION

One of the important goals of virtual reality systems is to create "presence" and to fool the user into believing that one is, or is doing something "in" the synthetic environment. Many researchers have defined and explained presence in different ways [31]. Historically, in the context of virtual reality, the concept of presence has been associated much with spatial perception as its informal definition of "feeling of being there" suggests. Pausch et al. associated immersion and presence to one's establishment of 3D reference in space [29]. Similarly, many studies have identified system elements that contribute to enhanced user felt presence, and many of them are spatial or perceptual cues such as providing wide FOV display, head tracking, stereoscopy, 3D sound, proprioception, virtual maps and landmarks, spatial interaction [7][11][19].

Other studies in presence have challenged this view and attempted to widen the concept to include psychological immersion, thus linking more high level and "non technological" elements (processed in a top down fashion) to presence such as story and plots, flow, attention and focus, identification with the characters, emotion, pre-knowledge, etc. [9][33]. One can argue that there is an (evolving) dichotomy within the concept of presence as illustrated in Table 1 (the table should be taken as an illustration, that is, in reality, the separation is not as clear cut).

Establishing a model of presence is important because it serves as one of the basis for designing virtual reality applications, and thus it is important to sort out the relationship within the dichotomy, whether they are in fact independent, complimentary or conflicting. In this paper, we experimentally study the relationship between two content elements, each representing the two axis of the presence dichotomy, perceptual cues for spatial perception and sustained attention for (psychological) immersion. Our belief is that spatial presence and a top down processed concepts such as voluntary attention have only very weak relationship, thus our experimental hypothesis is that sustained attention would positively affect spatial presence in a virtual environment with impoverished perceptual cues, but have no effect in an environment rich in them. Our hypothesis is partly based on the possibility that attention can compensate for the distraction by the cumbersome VR devices and strengthen the flow of the raw external sensory input.

In order to confirm the existence of the sustained attention in the experiment, fMRI (functional Magnetic Resonance Imaging) of the subjects are taken and analyzed as well. The use of fMRI offers a powerful technique to observe and analyze cognitive activities of the brain. There are only little previous researches on the effects or explanation of presence in terms of brain activities. Thus, it is also our hope to perhaps find any association of presence to a particular brain activity or pattern. However, we admit and acknowledge that such a possibility is slim at best because presence must be a high level concept resulting from a complex and distributed atomic brain activities rather than localized in some area or exhibited in a particular pattern. Even if it existed it would be extremely difficult to single it out from the current imaging technology and analysis method.

Table 1. The dichotomy within the concept of presence.

	Non-Spatial Presence	**Spatial Presence**
Nature	**Conceptual / Cognitive / Psychological / Social** (e.g. feeling of being in an abstract space or part of a story, "I felt like being James Bond")	**Perceptual / Physiological** (e.g. feeling of being in concrete space, "I felt like being on the Moon")
Indiv. Diff.	**More subjective**	**More objective**
Space [26]	**Conceptual / Abstract**	**Concrete / Physical**
Process	Formed as by-product of voluntary and conscious **top down processing (high level)** Involves rational, abstract and logical reasoning	Formed as by-product of involuntary **bottom up processing** of raw sensory cues **(low level)** Involves reflexive behavior responsive to stimuli
Factors	**Non technological (content)**[1] E.g. Story, Plot, Attention, Focus, Abstract Interaction, Role Playing, Emotion, Social Interaction, (Deliberate) non-realism, etc.	**Technological (form)** E.g. 3D Display, Bodily Interaction, FOV, Motion, Shadow, Graphic Realism, Texture Resolution, Simulation/Motion Realism, etc.

Characterization of the concept of presence directly goes to the purpose and utility of virtual reality which is often seen as superfluous technology or novelty rather than something that is required for the given application. For instance, if indeed it is possible to induce psychological immersion by manipulation of story, plots and abstract interaction, then, the digital contents such as the interactive story or games can be conveyed sufficiently using the conventional desktop interfaces rather than employing expensive and often difficult-to-use-and-engineer VR setups to create spatial contexts.

This paper is organized as follows. The next section discusses other body of research related to this work. Section 3 describes the main experiment and Section 4 reports the results. Finally the paper is concluded with a discussion of the results, summary and directions for future research.

2. RELATED WORKS

2.1 Presence

Presence or the sense of presence is defined as the degree to which participants feel that they are somewhere other than where they physically are when they experience the effects of a computer-generated simulation [3]. It is often dubbed as the "sense of being there" [30][31]. Many presence-related researches have looked at various "bottom up" perceptual cues that affect the level of user felt presence in the context of virtual reality [7][8][11][19][22][30][31][32][33][34][35][36]. For instance, Barfield et al. [7] investigated the sense of presence within virtual environments as a function of visual display parameters such as head tracking, stereoscopic cues, and geometric field of view. Their results showed that the level of presence was significantly higher when head tracking and stereoscopic cues were provided. Cho et al. [5] considered two major paths in the human brain, and classified the perceptual cues into "what" (for detail perception / object identification) and "where" (for spatial perception). They argued that the "where" cues (e.g. stereoscopy and motion) would contribute more to (spatial) presence than the "what" cues. Their results showed that the manner in which the "where" cues played a role was significantly different for user perception of mere visual realism and presence. Hwang et al. [22] constructed a model for presence by identifying the human perceptual subsystems and matching them to VR system elements.

There are also sizable body of work that considered high level and top down cognitive elements for presence. For instance, Sas et al. [21] investigated the relationship between presence and cognitive factors such as absorption, creative imagination, empathy, and willingness. Their results indicated significant correlations between presence and those cognitive factors. They showed that persons who are highly fantasy prone, more empathic, more absorbed, more creative, or more willing to be transported to the virtual world experienced a greater sense of presence. Note that in many of these works, the notion of presence may not always be just spatial.

Bystrom et al. proposed a model of interaction in virtual environments which they termed the Immersion, Presence and Performance (IPP) model. This IPP model described the conceptualization of the effects of display technology, task demands, and attentional resource allocation on immersion, presence, and performance in virtual environments [3]. Witmer and Singer also have provided a comprehensive categorization

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[1] Although these are important contributors to, for instance, conceptual presence, they may still contribute to spatial presence depending on the target of the cognitive activity.

and list of factors that form a substrate for describing presence such as control, sensory fidelity, and distraction [28].

Slater [24] has recently speculated on the existence "minimal" perceptual cues that are sufficient to invoke high presence when coupled with top down reasoning that creates a personalized experience. This hints on the possibility of deep coupling between perceptual cues and top down directed reasoning [24]. Nunez [15] constructed a three-layer connectionist model to explain and predict concept of cognitive presence. His model took input from two major sources: the perceptual modalities of the user (bottom-up processes), and the mental state of the user (top-down processes).

Waterworth et al. [26][27] developed a model called the FLS model of virtual / physical experience. The FLS model describes presence as having three dimensions: focus of attention (between presence and absence), the locus of attention (the virtual vs. the physical world) and the sensus of attention which is the level of arousal determining whether the observer is highly conscious or relatively unconscious while interacting with the environment. His model captures the user switching between two spaces, the physical (or virtual thought to be physical) and the abstract, in which different modes of reasoning is occurring.

2.2 fMRI and Virtual Reality

Using fMRI (functional magnetic resonance imaging) can be useful for in-depth studies of the mental states exposed to virtual reality. Hoffman et al. [10] demonstrated that subjects could still experience a strong illusion of presence during an fMRI despite the constraints of the fMRI magnet bore (i.e., immobilized head and loud ambient noise). Baumann et al. [2] developed a flexible virtual reality system platform for a variety of neurobehavioral experiments performed inside MRI scanners. Mraz et al. [14] has launched a research program to investigate the potential usefulness of the VR-fMRI combination. Our main purpose of using fMRI is to verify the existence of attention for counting task.

Ortunõ et al. [16] examined the changes in relative cerebral flood flow (relCBF) using PET (Positron Emission Tomography) during sustained attention tasks (e.g. mental counting). Studies have shown that sustained attention is associated with activations (significantly increased relCBF) in the inferior parietal, dorsolateral prefrontal, and anterior cingulate. Similarly, the activation in human brain during mental calculation was studied by many people [1][4][12][16][20]. Macar et al. [12] found significant supplementary motor area activation during attentional tasks requiring temporal estimation. Ortunõ et al. also observed right motor activation in their study. Macar et al. suggested, as Pardo et al. [17] and Posner et al. [18] did, that the SMA, together with DLPFC and inferior parietal, and anterior cingulate, would be related to attentional effort as a general factor. Ortunõ et al. described the motor activation as a supporting fact to link the primary motor region to attentional demands required for the cognitive activity of counting.

The role of parietal cortex was emphasized on attention and working memory. Participation of the parietal structures during these cognitive tasks has been related to the implication that the parietal cortex is part of the attentional networks in coordination with prefrontal and cingulate regions in studies of functional imaging. Ortunõ et al. confirmed this during an experiment with counting without auditory stimulation. As summarized by Mesulam [13], the parietal lobule, together with the prefrontal and cingulate regions, could be a convergence area which contributes to the sensory representation of *extra-personal space* and might have an important role in focusing attention on a target.

3. EXPERIMENT

The purpose of this study is to experimentally investigate the relationship between two content elements, each representing the two axis of the presence dichotomy, perceptual cues for spatial perception and sustained attention for (psychological) immersion. Our belief was that spatial presence and a top down processed concept such as voluntary attention have only a very weak relationship. In our experiment, subjects navigated through a virtual office with three differing levels (low, medium, high) of visual perceptual detailed cues. The subjects were either asked to carry out a counting task or not in the midst of the navigation. Our hypothesis was that sustained attention would have increasingly positive effects toward spatial presence for low fidelity virtual environments (impoverished spatial/perceptual cues), and have no effect in the high fidelity environment (rich in perceptual cues). Thus, we expected the effect of sustained attention would saturate as the environment became richer with spatial cues and its perceptual realism. In order to confirm the sustained attention actually occurred while carrying out the counting task, fMRI of the subjects were taken and analyzed

Figure 1: Synthetic environment with high visual detail.

Figure 2: Video of the office with the highest visual detail.

3.1 Experimental Design

Our experiment was designed as a 3×2 between-subjects experiment. There were two independent variables. One was the visual detail of the virtual environments (bottom up cues) and the other was the (sustained) attention factor (top down cue). The dependent variables were the total score of the presence questionnaire that subjectively rated the degrees of feeling of being in the virtual environments (i.e. spatial presence). The virtual environments consisted of the three different levels of visual detail: synthetic and low in detail (L), synthetic and high in detail (H), and real video (highest in detail) (V). The attention factor had two levels: with the attentive task (TO), and without it (TX).

Several kinds of visual detail cues were manipulated to create the low and high fidelity versions of the synthetic environment. Those were the geometric detail (polygon counts for objects), inclusion of shadow, object motion, and texture resolution. Due to the counting task, user motion was set to passive navigation with a fixed path. The display was provided in monoscopy as the special-purpose fMRI compatible HMD (Head Mounted Display) did not support stereoscopy. Figure 1 shows an example environment from the HTO case with the colored pencils which were to be counted by the subjects. Likewise, Figure 2 illustrates what the subject viewed in the VTO case, an actual video of the environment with real pencils.

In general there are four types of attentions: selective, focused, sustained and divided. In this paper, we focused on the effect of sustained attention which occurs throughout the experience within virtual environments. For this purpose, the counting task was chosen to induce sustained attention. The subjects were instructed to count the number of pencils with special colors in the synthetic environments or in video environment while navigating. The colors of the pencil body or the cap could be one of four: red, green, blue or white. The colors of the pencil and the cap were mixed in a random order. The subjects were asked to count the one with a red body with a blue cap.

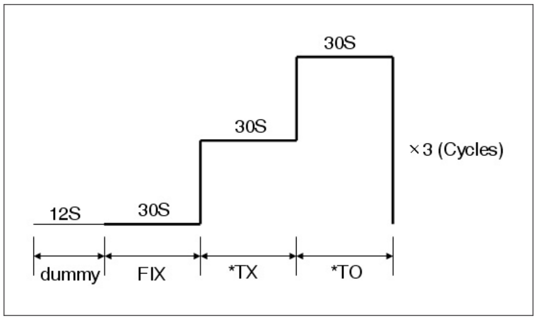

Figure 3: Block diagram of the experimental procedures

3.2 Experimental Procedure

There were a total of 36 subjects. Subjects group consisted of 32 university students and 4 high school students with the mean age of 21.5 and comprised of 30 males and 6 females. The mean of scores from the ITQ (Immersion Tendencies Questionnaire) [28] was 64.86.

Group I (12 subjects) experienced virtual environments in the fMRI system, and Group II (other 24 subjects) experienced virtual environments without it. The Boxcar design was used. Given a test environment with a visual detail level (L, H, or V), the subjects went through a series of tasks, FIX, TX, and TO, three times. FIX means a fixation task representing the resting baseline for comparison with activated state. At first, the scanning triggered the presentation of a crosshair (fixation baseline) for 12 seconds prior to the first task block. This fixation was followed by a block of 30 seconds blocks of TX and TO. This process was repeated 3 times for each L, H and V. The sequence of L, H and V was pseudo-randomly chosen. Figure 3 shows the block diagram of the experimental procedures. Thus for example, the first step might be FIX-HTX-HTO-FIX-HTX-HTO-FIX-HTX-HTO, the second, FIX-LTX-LTO-FIX-LTX-LTO-FIX-LTX-LTO, and the third, FIX-VTX-VTO-FIX-VTX-VTO-FIX-VTX-VTO.

Table 2. Presence Questionnaire

No	Question
q1	How much did you feel as being in the virtual environment?
q2	How much did the visual aspects of the environment involve you?
q3	How much did you feel that you were being there?
q4	How natural was your sense of objects moving through space?
q5	How much did your experiences in the virtual environment seem consistent with your real-world experiences?
q6	How much were you able to anticipate what would happen next?
q7	How well were you able to examine objects using the visual sense?
q8	How involved were you in the virtual environment experience?
q9	How quickly did you adjust to the virtual environment experience?
q10	How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

After finishing each step (e.g. FIX-HTX-HTO-FIX-HTX-HTO-FIX-HTX-HTO), subjects filled out the presence questionnaire. Subjects from the group I were instructed not to move their heads to insure head fixation. For this reason, they answered to the questionnaire with voice with minimal exchange of words. Subjects from group II plainly wrote their answers to the printed questionnaire.

3.3 Presence Questionnaire

We used ten questions based adapted from the Witmer and Singer's presence questionnaire [28] to rate the degree of feeling of being in the virtual office and other related qualities of the virtual experience. Our questionnaire largely considered spatial presence (only q8 and q10 concerned conceptual presence). Table 1 show the ten questions used in our experiment. Each question was answered in the scale of 0 to 10.

3.4 Experimental Devices

A 1.5T GE (General Electric) CVI Magnetic Resonance Imaging system installed at the Hanyang University Hospital (Kuri, Korea) was used to obtain the fMRI data. Subjects in the magnet wore a special MR compatible HMD from Resonance, Inc. The HMD had 30 degrees FOV and a screen resolution of 800×600, but did not support stereoscopy. As no interaction was involved, users simply donned the HMD and carried out the instructed tasks. For the Group II, subject's were covered with black drapes over their head (donned with the HMD with similar specifications) not to be distracted by the external environment. Figure 4 shows a Group II subject being tested.

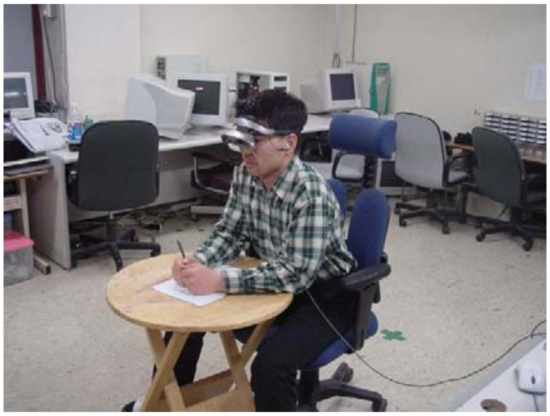

Figure 4: A Group II subject viewing the virtual environment with a head-mount display (the black drape cover is not shown for illustration purpose).

3.5 fMRI Data Analysis

The statistical analysis of the data was carried out using the Statistical Parametric Mapping program (SPM99) (Friston et al. [6]). The fMRI scans were spatially normalized using a nonlinear transformation to remove individual subject variability and transformed each brain into the Talairach and Tournoux atlas reference space [25]. The scans were then smoothed at 4 mm width with a 3D Gaussian filter to suppress noise and minimize any effects of normalization errors by increasing the sensitivity of the signal. Data from each participant were entered into a general linear model fixed-effect group analysis framework using SPM99. We used the conventional SPM analysis, and employed stimulus functions convolved with the standard SPM99 canonical hemodynamic response function. And in the assessment of SPM, we obtained t-contrast images for each subject. The five types of t-contrast images were obtained for the group analysis: TO - FIX, TX - FIX, L - FIX, H - FIX, V - FIX. These t-contrast images were used to analyze the global activations between subjects. For these images, a random-effects analysis was performed. Differences in the global activations between subjects were calculated using voxel-by-voxel two sample t-test and 1-way ANOVA. The resulting values constituted a statistical parametric map. The critical level of alpha was set at 0.001 (uncorrected for multiple comparisons).

4. MAIN RESULTS

4.1 Presence Scores

The results of ANOVA are tabulated in Tables 3, 4 and 5. Table 3 represents the results for the total presence score (which reflects mostly spatial presence). It shows that the means of the presence scores for each level in the visual detail factor (L, H and V) were significantly different ($\alpha = 0.05$, $Pr < 0.0001$). According to the SNK (Student-Neuman-Keuls) Test, the score for V was the highest, H the middle, and L, the lowest, as expected (also see Figure 5). On the other hand, the difference in presence scores between TO and TX was not statistically significant ($\alpha = 0.05$, $Pr = 0.1225$). The analysis also showed no significant interaction between visual detail factor and attention factor. ($\alpha = 0.05$, $Pr = 0.4319$). This result partially supports our hypothesis that spatial presence and attention have a weak relationship. In fact, the result shows they are independent and unrelated.

Table 3. Result of ANOVA. Dependent variable is total presence score and R^2=1.00

Source	DF	Anova SS	Mean Square	F value	Pr>F
Detail	2	16994.01	8497.00	61.33	<.0001
Task	1	81.89	81.89	2.50	0.1225
Detail *Task	2	22.62	11.31	0.85	0.4319

Table 4. Result of ANOVA. Dependent variable is presence score of q8 only and R^2=1.00

Source	DF	Anova SS	Mean Square	F value	Pr>F
Detail	2	113.53	56.76	21.66	<.0001
Task	1	14.00	14.00	12.31	0.0013
Detail *Task	2	0.01	0.01	0.01	0.9914

Table 5. Result of ANOVA. Dependent variable is presence score of q10 only and R^2=1.00

Source	DF	Anova SS	Mean Square	F value	Pr>F
Detail	2	50.36	25.18	10.29	<.0001
Task	1	11.57	11.57	13.31	0.0009
Detail* Task	2	0.29	0.14	0.14	0.4319

We also carried out the analysis for each individual presence questions. While, most questions exhibited similar results, significant differences in the answer ratings were found between TO and TX for q8 and q10. This is because q8 and q10 are questions that concern conceptual presence rather than spatial presence.

4.2 Brain Activations

The brain activations analysis using SPM showed significant differences in the brain pattern only between TO and TX. The significant areas of activation with the attentive task are listed in Table 6. Figure 6 shows the brain images rendered into the standard single subject image. It shows that the cingulate, inferior parietal, inferior frontal, middle frontal and sub-gyral regions were particularly activated. These activated regions are evidences of the sustained attention.

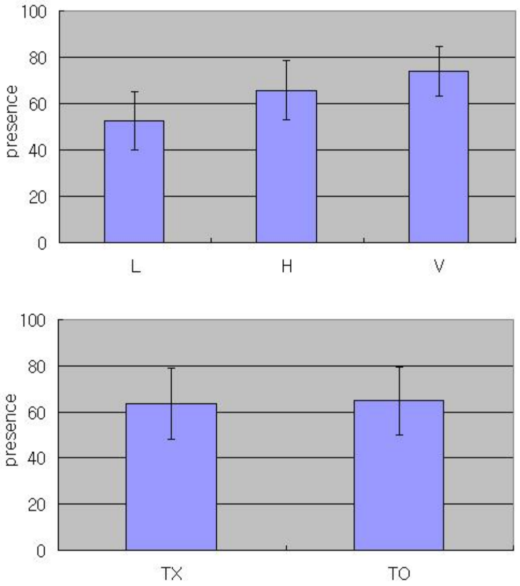

Figure 5: The effect of visual detail and attention on presence. There are significant differences among L, H and V (above), but none between TX and TO (below).

As for the performance, lower the fidelity of the environment was, better the performance. This can be attributed to the fact that the counting task was easier with simpler looking objects around. Whether there is a correlation between spatial performance and spatial presence remains an open issue. Note that this is different from the correlation between the existence of strong spatial cues and the level of spatial presence.

5. DISCUSSION

Our original hypothesis was that sustained attention would positively affect spatial presence in a virtual environment with impoverished perceptual cues, but would have little or no effect in an environment rich in them. The experimental results showed they were not related at all. The results for q8 and q10 only confirmed the obvious fact that conceptual presence occurs during an attentive task, by the user having to concentrate on the counting task.

Waterworth et al. [27] suggested in their FLS (focus, locus and sensus) model that sense of presence is the strongest when attention is most occupied by perception of the environment (physical or electronic), and the weakest when attention is most occupied with mental reflection. They explained that changes in the balance between conceptual (abstract) reasoning and perceptual (concrete) processing affect the nature of our experience of the world around us. Their FLS model suggested that the subjective duration depends on the amount of conceptual processing performed during an interval, relative to the level at which an individual habitually performs. For example, if conceptual processing has a heavy load, people's experience of duration is short and people pay little attention to the world around them. In those situations, they are "absent minded" and do not present in the world. And when the conceptual processing load is light, they have longer experience of duration and can frequently sample what is going on around them, whether natural or synthetic. In this sense, presence arises when people mostly attend to the currently present environment within and around the body.

Table 6. Brain regions associated with significant activation during counting task.

Regions	Side	BA	Talairach	t
Premotor	L	6	(36,-8,56)	4.44
Cingulate	R		(6,16,40)	3.86
	R	32	(6,20,42)	3.86
	R		(6,20,42)	3.51
Inferior Parietal	L	40	(-36,-36,40)	4.26
	L		(-52,-42,42)	3.84
	L	40	(-44,-36,44)	3.78
	R		(44,-44,42)	3.73
	R		(42,-46,48)	3.52
Inferior Frontal	L	47	(-26,30,-12)	4.03
	L		(-46,16,0)	4.02
	L		(-48,16,4)	3.62
	L		(-40,8,32)	3.53
Middle Frontal	R		(28,0,56)	4.07
	L		(-30,46,18)	3.90
	L		(-36,0,54)	3.78
	L	9	(-28,30,30)	3.69
Sub-Gyral	L		(-20,4,44)	4.39
	R		(22,-54,24)	4.09
	L		(-42,-16,-16)	3.97
	L		(-28,30,4)	3.68
	R		(26,-6,36)	3.58
	R		(14,22,20)	3.58
Extra-Nuclear	L		(-24,18,10)	4.23
	L		(-22,20,6)	3.74
Precuneus	L	19	(-34,-66,40)	3.90
Medial Frontal	L		(-20,2,48)	3.84
Thalamus	R		(10,-8,4)	4.59

Our result is consistent with that of Waterworth's model and we claim that introducing high level elements like attention, emotion, scripts do not really help user build a spatial model of the place and leave the user with feeling visiting a concrete place.

Our results may also be explained by the fact that spatial presence or spatial perception is largely a low level perceptual phenomenon that goes on involuntarily, while conceptual presence is high level top down, and voluntary reasoning. Thus the only way they can be coupled is when the target of the conceptual reasoning is the physical (or virtual) world itself (e.g. thinking about where the desk is). We can stipulate that high level cognitive elements such as story, plots and empathy with the characters can induced spatial presence when they have strong spatial connotation. For instance, an interactive story of the "Snow White" can conjure up a mental picture of castles, forests and dwarfs. Coupled with a consistent multimodal display, the overall presence can be maximized.

Even though people cannot afford to pay attention to the surrounding environments during the attentive task, but they still know that they are already in the synthetic environments or real environments and continue to receive perceptual cues processed automatically.

Interestingly, the debriefing session revealed a difference in spatial perception depending on the perceived difficulty of the task. Those who thought the counting task was easy showed tendency to feel increased presence by the inclusion of the task. This is another evidence of the reduced mental load on the conceptual processing leaving room for formation of higher spatial presence.

Finally, we acknowledge few problems with the way the experiment was carried out, mostly due to the restriction imposed by having to use the MRI equipment. For instance, the 30 seconds exposure to virtual environments may have been too short to induce sufficient immersion for the subjects. The MR compatible HMD only offered restricted field of view and head tracking was not possible. However, it seems unlikely the results would have changed by the addition of these mostly "spatial" cues.

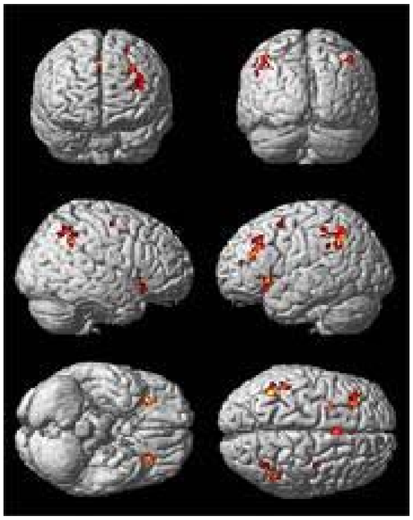

Figure 6: Brain Activation Associated with significant activation during counting task

6. CONCLUSION AND FUTURE WORKS

Inducing spatial presence in the virtual environments is an important goal of for many virtual reality systems, such as location based games. We performed an experiment to investigate whether non-spatial and conceptual cognitive activity might affect the perception of space (virtual or physical). From our experiment, sustained attention was found to be unrelated to spatial presence or spatial perception. The attention during the counting task was confirmed through the fMRI brain imaging to back up the validity of our study. We suspect that other high level purpose activities or elements such as story, plots and pre-knowledge will have little to do with spatial presence unless the target of the activities also involve the space itself (e.g. treasure hunt story, or pre-knowledge about the space). However, more studies must be done to confirm our suspicion. Experimenting with conflicting spatial contexts between the perceptual and conceptual cues may reveal interesting results. Another overlooked factor might be the sense of inclusion. While we investigated in the aspect of the general spatial perception of presence, what could be really important is the sense of self inclusion in the perceived space. Such a sense may indeed require combined effort of conceptual and perceptual cues.

The implication of the study is important for interactive multimedia or virtual reality system design. Employing expensive VR devices could be superfluous if the purpose of the system was non spatial. On the other hand, VR as a technology will have a unique value in providing strong spatial context for those applications that require it such as many training and educational systems.

7. ACKNOWLEDGMENTS

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