Formation of Spatial Presence: By Form or Content?

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Abstract

Spatial presence, among the many aspects of presence, is the sense of physical and concrete space, often dubbed as the sense of "being there." This paper theorizes on how "spatial" presence is formed by various types of artificial cues in a virtual environment, form or content. We believe that spatial presence is a product of an unconscious effort to correctly register oneself into the virtual environment in a consistent manner. We hypothesize that this process is perceptual, and bottom-up in nature, and rooted in the reflexive and adaptive behavior to react and resolve the mismatch in the spatial cues between the physical space where the user is and the virtual space where the user looks at, hears from and interacts with. Hinted from the fact that our brain has two major paths for processing sensory input, the "where" path for determining object locations, and "what" path for identifying objects, we categorize the sensory stimulation cues in the virtual environment accordingly and investigate in their relationships as how they affect the user in adaptively registering oneself into the virtual environment, thus creating spatial presence. Based on the results of series of our experiments and other bodies of research, we postulate that while low level and perceptual spatial cues are sufficient for creating spatial presence, they can be affected and modulated by the spatial (whether form or content) factors. These results provide important insights into constructing a model of spatial presence, its measurement, and guidelines for configuring location-based virtual reality applications.

Keywords--- **Spatial Presence, Model, Spatial Perception, Where, What, Form, Content, Brain, fMRI, Sensory Mismatch, Adaptation, Disorientation, Questionnaire, VR System Design, Dichotomy, Immersion.**

1. Introduction

Starting from the simple notion of "feeling of being there," presence has been developed into a multi-dimensional concept over the years. Scholars now generally agree that there are different types of presence, such as spatial presence, social presence, and psychological (or conceptual) presence [7]. Among them, "spatial" presence (also known as physical presence) refers to the sense of physical and concrete space, often dubbed as the sense of being there (e.g. virtual environment). Spatial presence bears particular importance to the virtual reality (VR) "technologists", interested in providing location-based experiences, because it is seemingly (although not proven) more dependent on the "form (or system)" factors of the VR content.

In fact, there has been a lot of debate over the so called form vs. content issue. In a recent article, Slater argued that presence was about "form," rather than "content" [13]. He stated that, " *... presence is the response to a given level of immersion ... presence is about form, the extent to which the unification of simulated sensory data and perceptual processing produces a coherent 'place' that you are 'in' and in which there may be the potential for you to act ...*". Our interpretation is that what Slater refers to as presence is actually "spatial" presence (rather than general presence) and naturally, he believes that it has more to do with low level spatial cues as perceived through a particular system configuration ("form"), and less with high level "content" factors like story, pictorial realism, attention, game elements, etc.

This paper theorizes on how "spatial" presence is formed by various types of artificial cues in a virtual environment, form and content included. We believe that spatial presence is a product of an unconscious effort to correctly register oneself into the virtual environment in a consistent manner. We hypothesize that this process is perceptual, and bottom-up in nature, rooted in the reflexive behavior to react and resolve the mismatch in the spatial cues between the physical space where the user is and the virtual space where the user looks at, hears from and interacts with. This view is in agreement with that of Slater in terms of the importance of the form factors.

In the rest of the paper, we go over series of experiments to test and confirm our theory on the formation of spatial presence in virtual environments. Starting with the premise, the relative importance of form factors to spatial presence and self registration, we first investigated in the relationships among various types of form factors as how they affect spatial presence. We make a note that although many studies have identified important factors to promoting user felt presence, their relationships and interactions have not been fully investigated [7]. Our initial hypothesis was that, among the form factors, spatial cues such as stereoscopy, shadow, and relative motion would be more contributing to spatial presence than detail cues such as geometric and texture resolutions. However, this hypothesis was disproved in our first experiments. This led to two other experiments, one that tested the effects (toward the spatial presence) of sustained attention (a content factor), and the length of exposure along with various form factors.

In the end, based on the experimental results (and other related work), we postulate that while low level and perceptual spatial cues are sufficient for creating spatial presence, they can be affected and modulated by the spatial (whether form or content) factors. Furthermore, we discuss the implication of this conclusion to constructing a model of spatial presence, measuring it and appropriately designing the questionnaire, and guidelines for configuring location-based virtual reality applications. We make a note that some procedural details of the experiments were omitted in the paper for lack of space. We only report results that are statistically significant with the p-value of below 0.005.

2. Related Work

2.1 Presence: The Dichotomy

One of the important and defining 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 [7]. 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 [5][7]. Pausch et al. associated immersion and presence to one's establishment of 3D reference in space [9]. 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 field of view (FOV) display, head tracking, stereoscopy, 3D sound, proprioception, maps/landmarks, and spatial interaction [7].

Other studies in presence have challenged this view and attempted to widen the concept to include psychological immersion, thus linking higher level and "non technological" elements (processed in a top down fashion) to presence such as story and plots, flow, attention and focus, identification/empathy with the characters, social interaction, emotion, pre-knowledge, etc. [7][10][11]. 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).

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 [17]	**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, etc.	**Technological (form)**	
		Where	3D Display, Bodily Interaction, Large FOV, Motion, Shadow, etc.
		What	Graphic Realism, Texture Resolution, Simulation/Motion Realism, etc.

2.2 Form Cues: "Where" and "What"

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

The visual system in our brain can be divided into two or more separate pathways. This separation starts to become evident at the level of the retina where two major types of cells, the M and P cells, can be found from which subsequent pathways (into Magnocellular and Parvocellular layers) are formed already within the primary visual cortex (also known as V1) [4]. Each of the pathways splits further into different regions in the visual cortex that have different functionalities. Regions along the P pathway seem to deal primarily with color, object shape and ultimately lead to the inferior temporal cortex which is known to mediate pattern and object recognition ("what" path). Regions along the M pathway are sensitive to orientation, movement and retinal disparity, and lead to the posterior parietal cortex that processes spatial and motion information ("where" path).

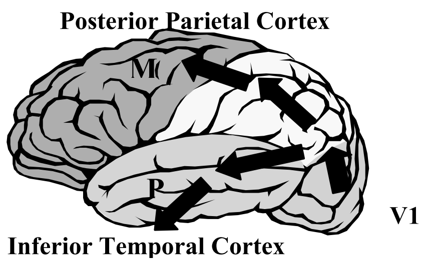

Figure 1: The what-where pathways in the visual cortex. The M carries information regarding space and motion for determining object location and the P primarily carries information regarding object local properties for object identification.

In our first experiment, we consider six visual cues: stereoscopy, object (gross) motion, user motion, motion detail, texture quality, and shape detail. The first three are considered "where" cues and the rest "what" cues[2]. Even though we use the words "where" and "what" for these cues from their basic characteristics, it should not be confused that "what" cues can still affect overall spatial perception and vice versa. For instance, in object recognition, researches have found that humans focus on those parts of the scene that are most informative in disambiguating its identity [6]. A similar model has been established for attention as well [6].

2.3 Cross Modal Integration / Resolution

It is generally accepted that multi-sensory feedback is beneficial to both presence and task performance in the context of virtual reality systems [7]. This is only provided that the feedback from each modality is consistent with one another, and the multi-sensory feedback (or input) is configured appropriately for the task at hand [8]. Multimodal sensory mismatch often results in the form of sicknesses, discomfort and other after effects [15]. In relation to the sicknesses, humans are also known to adapt given sufficient amount of exposure. In the process of adaptation, humans resolve the mismatch by constructing one's own interpretation of the situation, whether by suppressing one modality or fusing them together in some way [12].

3. Experiment I: Where vs. What

Our investigation started with an experiment to weigh the relative contributions toward spatial presence among different types of form factors, "what" and "where," first with the visual input only, then with both visual and aural.

3.1 Testbed Environment and Independent Variables

In this first experiment, spatial presence levels were measured (with a subjective questionnaire) after having the subjects experience test virtual worlds configured with different combinations of six visual presence elements. We built a simple virtual undersea world as the testbed for the experiment. Table 2 shows the summary of the independent variables and their level design. Figure 2 shows an example of the virtual undersea world presented to the subject during the experiment.

Table 2: Five independent variables and their levels in Experiment I-1 (Uni-modal Case).

Type	Variable	Levels	Explanation
Where	Stereoscopy	High	With stereo
		Low	No stereo
	User Motion	High	Fixed user navigation
		Low	View at fixed location
	Object Motion	High	Fish moves around
		Low	Fish stays in place
What	Motion Detail	High	With deformation (tail wagging)
		Low	No deformation (No tail wagging)
	Geometry	High	High polygon model
		Low	Low polygon model
	Texture	High	With texture
		Low	No texture

3.2 Experimental Procedure

Subjects, in a random order, looked at each of the 32 virtual undersea worlds projected on a 50 inch screen from a fixed location for 90 seconds[3]. After looking at each configuration, the subject was asked to fill out a presence questionnaire. The questionnaire comprised of four questions asking to rate the (1) visual realism of the objects, (2) one's ability to perceive locations of oneself and other objects, (2) the visual realism of the overall

[2] Our choice of visual elements comprises of those that can be varied by software control. For instance, the effect of field of view was not considered.

[3] Although there are 64 combinations of the independent variables, the Fractional Factorial experiment design allows analysis by testing only 32 subject groups.

environment, and (4) the feeling of being in the environment (spatial presence), in the scale from 0 to 100.

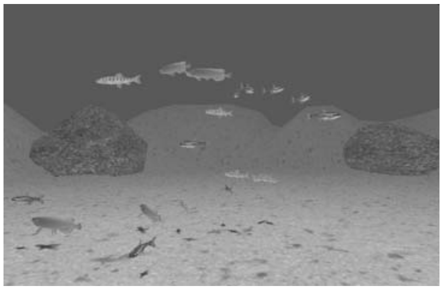

Figure 2: An example configuration of the virtual undersea world (Geometry=high, Texture=high, Stereoscopy or Motion can not be illustrated here).

3.3 Main Results

The ANOVA, simple effect tests, and regression analysis showed that the manner in which the visual elements played a role was significantly different for user perception of visual realism and spatial presence. Results showed that "where" cues played an increasingly more important role (with statistical significance) for spatial presence than for visual realism only, but with a marginal difference (See Tables 3). This was rather contrary to our expectation; we expected a land slide victory for the "where" cues, because intuitively spatial cues should be more important for spatial presence. However, we observed the interactions between several "what" and "where" cues played significant roles in creating spatial presence.

Table 3: Regression analysis. Relative weights toward the overall visual realism (R^2 = 0.97) and spatial presence of the environment (R^2 = 0.95). All results with p value less than 0.006.

Factor Types	Variable	Visual Realism		Spatial Presence	
		Rel. Wt.	Tot.	Rel. Wt.	Tot.
What	Geometry	**10.1**	**37.4**	**9.1**	**32.0**
	Texture	**27.3**		**22.9**	
Where (29.87)	Stereoscopy	**6.7**	**29.9**	**10.4**	**30.5**
	Object Motion	**16.3**		**14.4**	
	User Motion	**6.9**		**5.71**	
Interaction (23.07)	Geometry x Object Mot.	**6.7**	**23.0**	**8.78**	**30.1**
	Texture x Object Mot.	**10.7**		**14.11**	
	Texture x User Motion	**5.7**		**7.23**	

With such a marginal difference in the degrees of contribution between the "where" and "what", the results would not be so useful (e.g. guidelines for system configuration for spatial presence), because the sufficiency or saturation point[4] for the contribution of the geometric detail and texture resolution ("what") is neither known nor easily quantifiable, and perhaps depends on the user's individual background. This in turn also makes any analysis of the contributing weights among different cues, regardless of whether they belong to the "what" or "where" group, admittedly without merit for the same reason.

3.4 Bi-modal Case: Visual and Aural

Thus, a similar, but separate experiment was conducted to assess the effect of multimodality. A different testbed, an office navigation, was used and aural "where" (3D sound) and "what" (sound quality) cues were used in addition to the visual "where" (stereo, landmarks) and "what" cues (geometric detail and texture resolution) as the control factors. Our expectation was that with multimodality itself as a presence enhancing cue, the dependence of spatial presence on the "what" cue (as manifested in the first experiment) would be reduced. If we were to observe such a phenomenon, we would be able to expect other similar manipulations, such as adding interaction or other channels of sensory input to bring similar effects. However, contrary results were obtained, that is, the relative weights for the "what" cues dominated those for the "where" by about the ratio of 7 to 3. The "where" cues increasingly more important for spatial presence over visual realism was observed as was in the first experiment. As suspected with the results of the first experiment, the individual difference in detail perception ("what") seems to make the comparison between "where" and "what" inconclusive.

4. Experiment II: Where and What vs. Time

In order to neutralize the individual difference in the contribution of "what" (and even for "where") cues, the same experiment was run with another independent variable, the length of exposure time. Our hypothesis was that with a sufficient time of exposure, both the effects of the "what" and "where" cues would be saturated, and after that point, the true comparison between the "what" and "where" cues could be made.

4.1 Experimental Design and Procedure

The same testbed (i.e. undersea world) used in the first experiment was used again, but only four configurations were compared. The four test configurations were selected to form the "high what / high where," "high what / low where," "low what / high where," and "low what / low where" groups. The "where" factors constituted the use of stereoscopy, gross object motion and shadow. The "what" factors constituted the levels of

[4] In a separate experiment, we verified that there exist saturation points for contribution by the "what" cues, although where the saturation point occurred would not be generalizable [2]. There are other researches that point to the same results as well [7][18].

polygon counts and texture resolution for the object models.

The level of user felt presence was measured in a different way. All the subjects (32 in total) experienced the various configurations (in a random order) for 10 minutes. The level of presence was measured basically the same way by asking the subject to rate "the degree to which feeling being in the undersea world," but at every one minute in the scale of 0 to 100 during the course of the 10 min. experiment. No visible symptoms of simulation sicknesses were observed from the subjects.

4.2 Main Results

The main result is shown in Figure 3. The level of presence generally increased for all four test combinations with longer time of exposure. The graph in Figure 4 also clearly shows that the level of presence saturating, and near and at the saturation regions, it is the "where" cues that expedites and becomes more important in promoting spatial presence. The relative weights in the early part of the exposure are irrelevant because it is presumed that their effects have not kicked in sufficiently, and individual differences create a large variance.

Figure 4 shows the change in relative weights toward spatial presence among the variables: time (labeled "intercept", diamond), where (triangle), what (square) and the interaction ("x"). With longer exposure time, the contribution of the "where" cues becomes the most important. It is also interesting to observe that at the end of 10 minutes, there is no interaction between the "where" and "what" cues. This is contrary to the results of the Experiment I where much interaction was observed. The interaction in Experiment I could have been caused by the multi-sensory conflict due to the lack of sufficient exposure (only 90 seconds).

5. Experiment III: Form vs. Content

While Experiment I and II concerned the relationship between the form factors, "where" or "what", the purpose of Experiment III was to study the relationship between two 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 perception 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 cues. The subjects were asked to either to count certain objects 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.

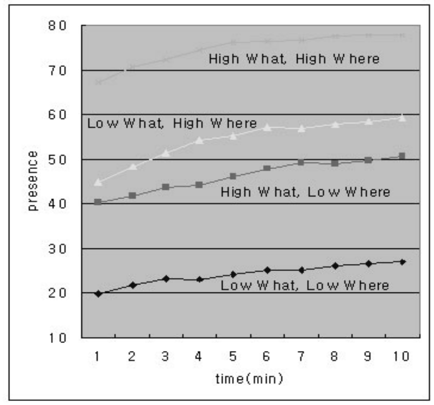

Figure 3: The level of presence along time of exposure among four tested configurations of Experiment II.

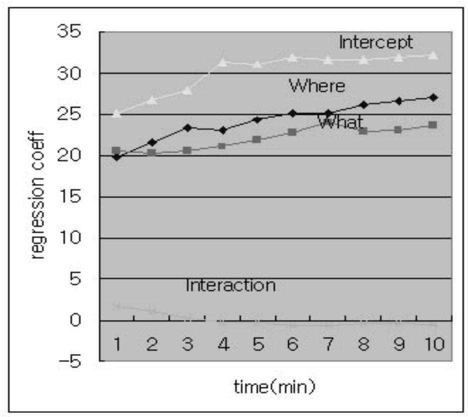

Figure 4: The relative weights toward spatial presence among the variables: time (labeled "intercept", diamond), where (triangle), what (square) and the interaction ("x"). With longer exposure time, the contribution of the "where" cues becomes the most important.

5.1 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 (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 in a fixed path. The display was provided in monoscopy as the special-purpose fMRI compatible HMD (Head Mounted Display) did not support stereoscopy.

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 red body and blue cap.

5.2 Experimental Procedure

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. 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.

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.

We used ten questions 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. Each question was answered in the scale of 0 to 10.

5.3 Main Results

The results of ANOVA are shown in Figure 5. The first figure of Figure 5 represents the results for the total presence score. 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). On the other hand, the difference in presence scores between TO and TX were 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.

The brain activations analysis using SPM showed significant differences in the brain pattern only between TO and TX. 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.

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.

Waterworth et al. [17] suggested in their FLS (focus, locus and sensus) model that sense of (spatial or physical) 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.

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). 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. However, the high level cognitive activity may be inhibiting the spatial memory construction process of the perceptual system.

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.

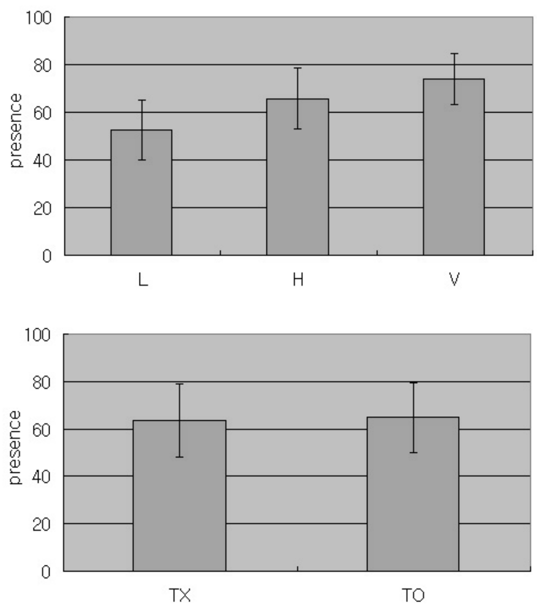

Figure 5: The effect of visual detail and attention on presence. There are significant differences among L, H and V (above), but none between TX and TO (below).

6. Summary and Discussion

6.1 Model of Spatial Presence

In some sense, it is obvious that spatial or "where" cues are important for spatial presence. Despite the common sense, it seems there is a big confusion due to many different definitions of presence and conflicting results from various studies that considered different types of cues as contributing factors to presence. However, very little of these studies considered the effects of saturation and time of exposure. Our position on how spatial presence is formed is that it is a product of basically a bottom up perceptual process that gathers spatial cues to actively place and register the user in the seemingly surrounding environment and that it takes some amount of time. Our results show that this process can be affected by provision of spatial perceptual cues "to set the stage" [3]. We further speculate that, the spatial cues must be consistent with the external stimuli to be effective. As for the content factors, we believe that they must be spatial in nature to create synergistic effect with the form factors. Thus, a spatial attentive task (e.g. search) with rich form factors would have created the highest possible presence. Our model is depicted in Figure 6. Slater has similarly 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 [14]. Our model further extends this idea.

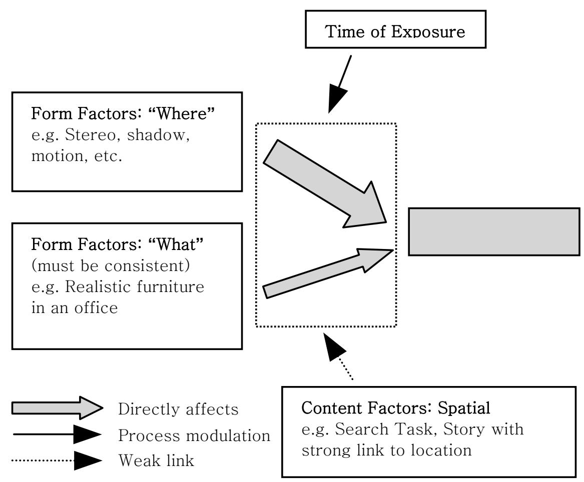

Figure 6: Contributing factors to spatial presence.

6.2 Measurement of Spatial Presence

As spatial perception lies in the core of spatial presence, measurement of spatial presence can be carried out by testing various spatial memory and behavior. Spatial presence can be viewed as a type of spatial representation with particular characteristics, for instance, a sense of inclusion, appropriate size, and perspective (e.g. ego-center). In the Experiment II, in addition to the spatial presence, the size characteristics were asked of the subjects, and spatial presence (and its change according to time) correlated highly with an appropriate size perception (e.g. large enough to include the user), another evidence of a gradual registration of oneself into the environment. In addition, the level of presence must be linked to the concreteness of this representation strengthened by the amount of cues and time of exposure. Slater et al. has already used the level of concreteness of spatial cognition as part of his presence questionnaire [16].

6.3 VR System Design

The implication of the study is important for interactive multimedia or virtual reality system design. Employing expensive VR devices will 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. 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.

7. Conclusion

Establishing a model of presence is important because it serves as one of the basis for designing and evaluating virtual reality applications. A model of presence refers to a detailed analysis of the contributing elements and their mutual interactions. In this paper, we have argued for a model for spatial presence based on results from a series of experiments, manipulating various types of artificial cues. We believe that spatial presence is a product of an effort to correctly register oneself into the virtual environment and this process is perceptual, and bottom-up in nature, rooted in the reflexive behavior to react and resolve the mismatch in the spatial cues between the physical space where the user is and the virtual space where the user looks at, hears from and interacts with. In particular, we postulate that while low level and perceptual spatial cues are sufficient for creating spatial presence, they require sufficient amount of time to take effect, and can be affected and modulated by the spatial (whether form or content) factors. More studies are needed and planned to further verify our proposal.

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