가상과 실제 손의 동기화를 통한 촉각환상 유발연구

구정훈, 김호성*, 김광욱, 한원용, 이장한*, 김선일
한양대 의대 의용생체공학과, *싸이코텍

The Tactile Illusion evoked by a synchronous Visual Stimulus on Virtual and Real Hand

Jeonghun Ku, Hosung Kim*, Kwanguk Kim, Wonyoung Hahn,
Jang Han Lee*#, Sun I. Kim
Dept. of Biomedical Engineering, College of Medicine, Hanyang University
*Psychotech

Abstract

The virtual reality (VR) technology can provide various stimuli, including, visual and auditory stimuli, simultaneously in the virtual environment and encourage the user to interact. Virtual reality is a set of computer technologies, which when combined, provide an interactive interface to a computer generated world. In this world the subject can see, hear and navigate in a dynamically changing environment in which he participates as an active player, by modifying the environment according to his will. Moreover, the subject can get a feeling for the virtual environment in much the same way as one feels real life situations. In the real world, a plethora of information from various modalities may be in conflict, and modulate each other to form an illusion. In this study, we investigated whether a tactile illusion on a real hand could be evoked by a virtual stimulus, the time required to generate this illusion and its duration. This study shows that the illusion occurred, and that was correlated with presence score in the virtual environment.

Keywords: Virtual Reality, Tactile illusion, Virtual hand, Rubber hand, Presence

Introduction

Many events in everyday life are registered by the sense organs of more than one type, for example by both the eyes and the ears. Consequently, the coordination and integration of information derived from different sensory systems is essential for providing a unified perception of our environment, and for directing attention and controlling movement within the environment. The capacity of the central nervous system to combine inputs across the senses can lead to marked improvements in the detection, localization, and discrimination of external stimuli and to faster reactions to

#Corresponding author : Jang Han Lee (clipsy@unitel.co.kr)
Sungdong P.O.Box 55, Seoul, 133-605, KOREA.
TEL : +82-2-2291 1675
FAX : +82-2-2296-5943

those stimuli. In addition, many stimuli from various modalities might be conflict, modulate each other or create an illusion.

A number of researches have reported a visual illusion can be induced by sound, for example, a single flash of light is accompanied by multiple auditory beeps, or the single flash is perceived as multiple flashes [1, 2]. In addition, a strong crossmodal integration can also occur as an emergent attribute of dynamic arrays, specifically the direction of apparent motion [4]. Investigators have used the Event Related Potential (ERP) in order to determine the modulation of somatosensory cortex activity by a non-informative view of the stimulated body site with concomitant enhancement of tactile acuity in normal subjects [5] and, accordingly to answer whether the cross-modal influence on visual perception occurs at the level of the modality specific visual pathway or later [3]. A tactile illusion, it could be referred to an alien limb [6]. The illusion has been explained by the spurious reconciliation of visual and tactile inputs reflecting functional connectivity. It was also investigated in schizophrenia [7]. However, all these researches were base on real-life illusions.

The virtual reality(VR) technology can provide various stimuli simultaneously in a virtual environment, which cause the user to interact, providing visual and auditory stimuli [8]. Virtual reality is a set of computer technologies, which when combined, provide an interactive interface to a computer generated world. VR technology combines real time computer graphics, body tracking devices, visual displays, and other sensory input devices, which immerse a participant in a computer generated virtual environment. The subject can then see, hear and navigate in a dynamically changing scenario in which he participates as an active player modifying the environment according to his interventions. However, because of technological constraints little research has been conducted on whether this kind of illusion could be evoked in the Virtual Environment except for a study on haptic perception [9].

Therefore, we investigated whether a tactile illusion on a virtual hand could be evoked by virtual stimulus, and how long it takes to create such an illusion and its duration.

Materials and Methods

1. Subjects

24 undergraduate volunteers participated in this experiment. They were right-handed males, of average age 22.12 years (SD = 2.57).

2. Instrument

The virtual reality system for providing stimulus consisted of a Pentium IV PC, DirectX 3D Accelerator VGA Card, Head Mount Display (HMD , i-visor DH-4400VPD), 3DOF Position sensor (Intertrax2). The PC with a 3D Accelerator VGA Card generates real-time virtual images for the subject to navigate. Aposition sensor transferred a subject's head orientation data to the computer.

The virtual environment consisted of a virtual human in a room with a gimlet nearby the virtual hand. The gimlet moved forwards and backwards at the same time as a real tactile stimulus produced by an air-puff and controlled by a computer (See Figure 1).

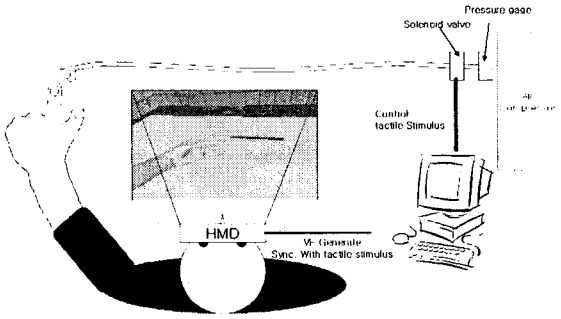

Figure 1. Diagram of Experimental Setting

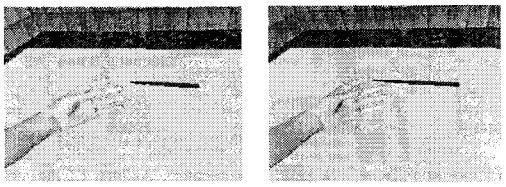

Figure 2. The virtual arm and gimlet

3. Procedure

Subjects were individually seated at a desk wearing virtual reality (VR) equipment (HMD with a position tracker). Subjects were asked to place their left arm on the desk in a position to that of virtual arm. They couldn't actually see their own left arm, and could only see the virtual arm, because the HMD covered their eyes completely. Subjects were instructed to immerse themselves in the virtual environment and to respond when they didn't feel a tactile stimulus.In each session of 5 sessions, a tactile stimulus was provided 60, 50, 40, 30, and 10 times in combination with a visual stimulus, (V+T), and a visual only stimuli intermittently applied until the subject responded affirmatively. When he/she responded to the visual only stimulus, the next session was started (See Figure 3). Based on the subject's behavior the following were noted, 'time to evoke the tactile illusion', 'the lasting period', and 'the correlation between the duration and the period'. After the testing experience, subjects completed a questionnaire that requested; a description of the subjects experience, an affirmation or denial of the occurrence of nine specific perceptual effects, which was modified to fit this experimental setting (See Table 1)[6], and subjected were also asked to complete a VR questionnaire, which requested details of their VR experience and the compatibility of VR, Witmer's presence questionnaire (PQ) and the immersive tendency questionnaire (ITQ)[10].

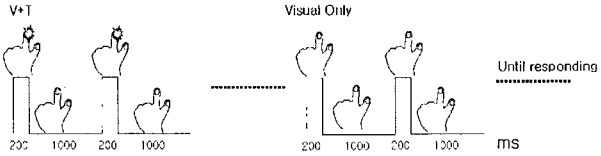

Figure 3. Stimulus provided in the experiment

4. Data Analysis

Scoring for each of the nine perceptual effects was high for affirmation of the illusion and low for the denial of the illusion. Scoring was established as follows: ---(1), --(2), -(3), 0(4), +(5), ++(6), +++(7). In addition, we defined an illusion index as, the mean score for all perceptual effects. Presence scores were average PQ scores, and the score of negative questions were reversed. In addition, the correlation between the subscales of PQ and the illusion index was investigated.

Table 1. Illusion questionnaire for the virtual hand experiment range from 'agree strongly'(+++) to 'disagree strongly'(---)

1. It seemed as if I were feeling the gimlet's touch in the location where I saw the virtual hand touched
2. It seemed as though the touch I felt was caused by the gimlet touching the virtual hand
3. I felt as if the virtual hand were my hand
4. It felt as if my (real) hand was drifting towards the right (towards the virtual hand)
5. It seemed as if I might have more than one left hand or arm
6. It seemed as if the touch I was feeling came from somewhere between my own hand and the virtual hand
7. It felt as if my (real) hand was becoming 'virtual'
8. It appeared (visually) as if the virtual hand were drifting towards the left (toward my hand)
9. The virtual hand began to resemble my own (real) hand, in terms of shape, skin tone, freckles or some other visual feature.

Results

No significant behavioral characteristics were observed because most of the subjects responded as soon as the air-puff stimulus disappeared though a few subjects showed a delay between the air-puff stimulus disappearing and tactile-stimulus feeling disappearing.

However, from the perceptual effect report made by the subjects, it was evident that an illusion had occurred (See Table 2).

Table 2. The Perceptual Effects of Virtual Hand Illusion (n=24)

Modified cohen's questions in table 1	Mean	SD
Question 1	3.833	2.099
Question 2	3.833	1.857
Question 3	3.291	1.680
Question 4	3.083	1.639
Question 5	3.083	1.717
Question 6	3.916	1.886
Question 7	2.916	1.612
Question 8	2.625	1.279
Question 9	2.375	1.312
Index	3.430	1.160

The presence score was 159.13 (SD=35) and the immersive tendency score was 118.25 (SD = 16.42). The scores of the PQ and ITQ subscales are shown in Table 3.

Table 3. The subscale scores of PQ and ITQ (n=24)

		Mean	SD
PQ	control factor	61.08	16.26
	sensory factor	51.25	11.89
	distraction factor	14.25	4.65
	realism factor	26.21	7.88
	Nothing	6.33	1.69
PQ total (240)		159.13	35
ITQ	involvement factor	43.67	8.48
	focus factor	42.79	6.21
	game factor	10.63	3.85
	Nothing	21.17	4.12
ITQ total (200)		118.25	16.42

A correlation was found between the illusion index and the presence score ($r=0.539$, $p<0.01$), but the immersive tendency score was not significantly correlated to the illusion index. In particular, the control factor and sensory factor in PQ were correlated ($r=0.483$, $p<0.05$; and $r=0.543$, $p<0.01$). The question 1 in the illusion

questionnaire was significantly correlated with prior experience (r=-.0414, p<0.05), and 5 and 6 were significantly correlated with control factor and sensory factor in the PQ and with the PQ score, and 5 was correlated with involvement factor in the ITQ. Question 8 was correlated with the sensory factor in the PQ.

Table 4. The correlations among the perceptual effect, PQ and ITQ

Perceptual effect questions	Experience, PQ and ITQ	r
Question 1	Experience	-0.414*
Question 3	Control factor in PQ	0.397
Question 5	Control factor in PQ	0.054**
	Sensory factor in PQ	0.425*
	PQ total score	0.464*
	Involvement factor in ITQ	0.414*
Question 6	Sensory factor in PQ	0.526**
	Realism factor in PQ	0.413*
	PQ total score	0.425*
Question 8	Sensory factor in PQ	0.435*
illusion index	Control factor in PQ	0.483*
	Sensory factor in PQ	0.543**
	PQ total score	0.500*

* p<.05 ** p<.01

Discussion

In this study, an illusion caused by a virtual hand was investigated. However, no behavior characteristics were observed. The reason for this might be due to differences between real and virtual, the period of stimulus providing and the instruction to respond when the subject didn't feel the touch. However, that the illusion occurred was supported by the illusion index, which was high, and the subject's verbal report.

Though there were no behavioral characteristics, this study shows that illusions can be created by a virtual environment and most of that the majority of participants felt that virtual hand appeared to be their hand. This result is coincident with the result of Botvinick and Cohen's Rubber Hand Illusion experiment and with Peled's experiment with schizophrenic patients. In particular, the correlation between presence score and the illusion index shows that presence in virtual reality serves a very important role in evoking the illusion. The result of this study that illusion can be occur supports the notion that virtual reality can induce real feelings.

Acknowledgement

This study was funded by a grant of the Korea Health 21 R&D Project, Ministry of Health & Welfare, Republic of Korea. (02-PJ1-PG11-VN01-SV03-0060).

References

[1]Ladan S., Yukiyasu K., & Shinsuke S. (2002). Visual illusion induced by sound. *Cognitive Brain Research,* 14, 147-152.

[2]Shams L., Kamitani Y., & Shimojo S. (2000). *Nature*, 408, 788.

[3]Ladan S., Yukiyasu K., Samuel T., & Shinsuke S.(2001). Sound alters visual evoked potentials in humans. *Cognitive Neuroscience and Neuropsychology*, 12(7), 3849-3852.

[4]Salvador S.F., Jessica L., Michael G., Charles S., & Alan K.(2002). The ventriloquist in motion: Illusory capture of dynamic information across sensory modalities. *Cognitive Brain Research,* 14, 139-146.

[5]Marisa T.C., Steffan K., and Patrick H., (2002). Vision modulates somatosensory cortical processing. *Current Biology*, 12,

233-236.

[6]Botvinick M., and Cohen J.(1998). Rubber hands 'feels' touch that eyes see. *Nature*, 391, p756.

[7]Peled A., Ritsner M., Hirschmann S., Geva A.B., & Modai I.(2000). Touch feel Illusion in schizophrenic patients. *Biol Psychiatry*, 48, 1105-1108.

[8]Popescu, G.V.(2002). Multimodal interaction modeling. *Handbook of Virtual Environments Design, Implement, and Applications.* New Jersey ; LEA Inc.

[9]Srinivasan, M.A., Beauregard, G.L., & Brock, D.L.(1996). The impact of visual information on the haptic perception of stiffness in virtual environments. *Proceedings of the ASMEDynamics Systems and Control Division*, 58, 555-559.

[10]Witmer B.G., & Singer M.J.(1998). Measuring presence in virtual environments: A presence questionnaire. *Presence*, 7(3), 225-240.