Evaluation Study of Virtual Reality both within the Human Body and within Society

Tohru Ifukube

Research Institute for Electronic Science, Hokkaido University, Sapporo 060, JAPAN
ifukube@sense.hokudai.ac.jp

Abstract

This paper briefly describes an evaluation study of virtual reality (VR) within the human body and within society as well as an author's research approach to the study of VR based on sensory substitute research. The former includes some examples of an application study related to the medical field and aid technology for the disabled. Furthermore, some expected influences of VR on both the human body and society are mentioned from the viewpoint of cognitive and social sciences. In the latter, the author mentions how the research regarding the sensory substitutes have been related to the VR studies and also introduces a research project of mixed reality that has begun this year.

Key words: Virtual Reality, Evaluation Study, Sensory Substitute, Mixed Reality

1. Introduction

Before advantages and disadvantages of VR technology have been clarified, the technology has rapidly spread to various areas such as entertainment, education, medicine, multimedia, and the arts. The purpose of our research is to evaluate the influence of the VR technology on the human body and society from the viewpoint of bio-medical, cognitive, and social sciences. In the evaluation of the influence on the human body, fatigue caused by autonomic nerve stimulation and the influence on one's equilibrium produced by a moving visual stimulation were investigated based on the bio-medical approach. The research purpose also includes an application of VR technology to the medical field, especially to surgery using 3-D bio-medical images which are superimposed on the human body. The application to aid technology for the elderly and the disabled is one of the research purposes. A VR game's influence on the sensation and perception was explored using high school students who play video games. Furthermore, an experiment was conducted to examining the effects of violent video games on subsequent aggressive behavior. After the author mention the above evaluation studies, this research approach will be related to sensory substitute studies and a mixed reality project begun this year in order to evaluate the influence of VR stimulation to the human body .

2. Results of Evaluation Study supported by Japanese Ministry of Education entitled "Basic Study of Virtual Reality "

The most concrete result was obtained from a medical application which was carried out by Iseki's research group[1]. They have designed a three dimensional image-guided navigation system called "Volumegraph" to evaluate the location of the operative field in neurological surgery for the reduction of surgical intervention.

Fig.1 an example of volumegraph image

The volumegraph is a kind of augmented reality technique which is useful for minimally invasive surgery. By using the technology, a three-dimensional (3-D) plotter can display 3-D images in the air by a beam light. The images can be superimposed on to the patient's head and body via a semi-transparent mirror as shown in figure 1.

These techniques were applied to the navigation system of neurosurgical operations. The 3-D data obtained from CT and MRI scan before the operation were processed by a computer. The image data were applied for preoperative investigations to recognize the 3-D structure of organs and tumors. These reconstructed 3-D images were superimposed and registered on to the patient's head according to registration marker. The application of augmented reality in the surgical field facilitates a neurosurgical intervention. This system will even be used in skull base surgery without distortion of perception. In this way, a surgeon could operate easily and accurately by using the volumegraph.

The application of VR technology for the elderly has been carried out by Dohi's research group. The purpose of this research is to create a VR system which may give moral support for the elderly who live alone. The system will be able to present images which help the elderly to relax. In order to prevent the images from harmful influences such as motion sickness, Ifukube's research group has investigated the influence of moving images in the area of far peripheral vision on one's sense of equilibrium.

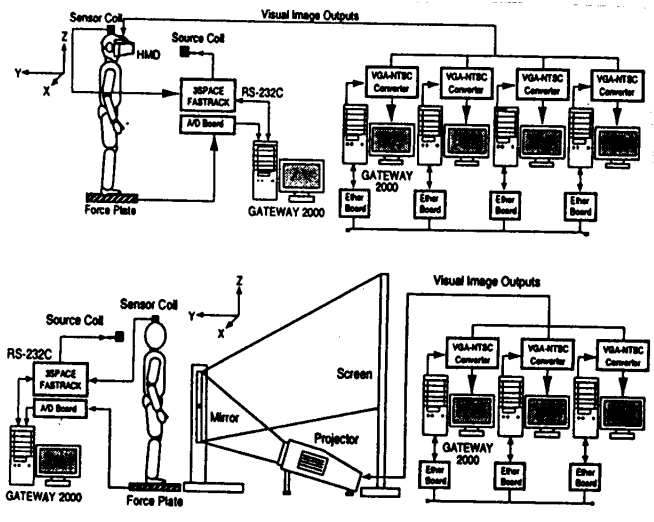

Fig. 2 Two display methods on far peripheral vision

Two types of visual displays were constructed: an HMD and a large screen. These can display the moving images in the area of far peripheral vision at a range of 140 degrees as shown in figure 2. Center of gravity for the subjects was measured while displaying the moving stripes using the HMD and the screen. From the experimental results, the center of gravity shifted according to the moving stripes and became more pronounced as the visual field increased in both cases of HMD and the screen. Comparing the data obtained from the HMD stimulation with those obtained from the visual stimulation displayed on the screen, it was found that the HMD stimulation had a stronger influence on the movement of the center of gravity than the stimulation displayed by the screen as shown in figure 3.

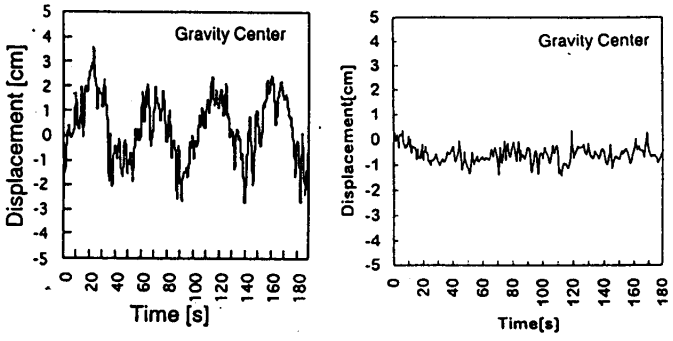

Fig. 3 Center of gravity. Left: HMD, Right: Screen

Subjective reports supported the above phenomenon, leading one to suspect the HMD stimulation on the far peripheral vision may cause motion sickness.

Munetaka's research group developed an interactive educational game utilizing an audio virtual reality system to improve children's audio localization skills[2]. The game was designed to produce real time audio feedback which allows two learners, called the 'chaser' and the 'escapee' respectively, to explore a virtual audio space interactively. An experimental study was conducted to examine the effectiveness of the educational game. The subjects consisted of three congenitally blind junior high school students who have good binaural listening skills. Two pre-post tests were conducted. One aimed at examining improvement in the practical use of audio localization skills based on the idea of 'floor volley ball' (a popular sport among the blind). The other test examined how much their game skills improved. After finishing the trials, all subjects showed a significant gain in accuracy. Subjects also reduced their time needed to catch the direction of a sound source in the game. These results

indicated that the system was effective for blind students in helping them to refine their audio localization skills. This finding encourages further use of audio virtual reality technology for enhancing special education.

In order to evaluate how concurrent sounds are processed in the human brain, Imaizumi's research group has investigated auditory processing from the viewpoint of bio-medical approach using a magnetoencephalograph[3]. Concurrent auditory stimulation was made by overlapping a 10 ms isolated burst (/k/) on a 500 ms isolated word /tooka/. In most cases, listeners do not pick out the burst (/k/) as a 'click' in the last syllable of the word /tooka/ and the middle of the long /o/ in /tooka/. Instead they perceive the burst to be part of a coherent auditory stream of /tooka/. On the other hand, they do pick out the isolated and overlapped burst (/k/) as a distinctive 'click'. Listeners perceived the burst (/k/) as a click having no particular phonemic features, whereas the overlapped burst (/k/) was perceived to be a background click separate from the word /tooka/. In order to investigate whether or not this phenomenon is caused by simultaneous parallel activities within the auditory cortex, they used a SQUID magnetometer (37-ch) which can measure the elicited magnetic field over the right and left hemisphere (temporal cortex) during auditory stimulation. From the experimental results, they concluded that segregated auditory streams representing concurrent sounds are spatially mapped within the auditory cortex via simultaneous parallel activities of at lease partially different neural populations.

It has been known that some joint problem solving can be effective compared to solo performance and can lead to better understandings. Miyake's research group has been investigating the effect and is going to apply the analytical results to understand the problem solution process in the virtual environment. Baba's research group has been investigating the influences of VR games on media identity using high-school students who play VR games[4].

Table I:Classification of Influences of VR Technology (1)

Causes/Levels	Physical Level	Cognitive Level	Social Level
Formal Properties	• Nearsightedness • Video game epilepsy		
Cognitive Properties	• "Simulator" sickness		• Appearances of new social relations
Social Properties	• Loss of strength	• Fabrication of "facts"	• Military use

Note: Most of the above influences are not scientifically certified as correct.

Table II: Classification of Influences of VR Technology (2)

Cause/Continuance		Cognitive Level	
		Temporary influences	Continual influences
Cognitive Properties	Application specific	• Increase in aggressiveness • Loss of keen senses • Loss of sence	• Social maladjustment • Acquisition of <->Loss of old once
	VR-general	of existence -Confounding reality	a new literacy of media with virtual reality -Functional disorder in sensory integration

Note:Most of the above Influences are not scientifically certified as correct

They first categorized the influences of virtual reality technology and discussed them. In table I, they classified the influences of VR technology along two axes: the causes of the influences of VR technology and the levels at which such influences are felt. The vertical axis is related to the supply side of VR technology. They divided this axis into three categories. The horizontal axis is related to the receiving side of VR technology. They also divided this axis into three categories.

Table II represents the shaded section of Table I in greater detail. As this category of influence is closely connected with identity and media, they used the term of "influence on media identity" to refer to the influence in the category. They mentioned that this categorization will be useful to evaluate the influence of VR games on media identity.

Last April, they distributed a questionnaire on media activities to 834 high school students. Nearly half of the subjects were female. In this analysis, they focused on the difference between Virtufighter (VF) and Street-fighter (SF). These are the top two most popular fight-simulating games in Japan. Nascent VR technology such as texture mapping and 3-D modeling is fully applied to VF. On the other hand, SF uses traditional animation technology. From the analysis of the subjective reports, cognitive properties of VR applications could have influences at a cognitive level, although video games, including VF, have little influence on personality as regards aggressiveness, extroversion, inferiority, progressiveness, sympathy, etc. Moreover, the cognitive process bears relationship to susceptibility to other media. This analysis cannot show conclusively the influences of VR video games, but it suggests the possibility that some influences of VR cannot be controlled.

An experiment was conducted by Sakamoto to examine[5]: (a) effects of violent video game use on subsequent aggressive behavior, (b) variables moderating the effects, and (c) processes mediating the effects. Fifty-

two female students at Ochanomizu University in Tokyo were randomly assigned to one of five conditions. Those were: the condition where the participants played a real game (Virtua Cop), the one where they played an unreal game (Space Invader), the one where they merely watched the real game, the one where they merely watched the unreal game, and the control condition where they watched a neutral film. After the participants played or watched the game or film, they were given the opportunity to administer electrical shocks to a confederate. The strength and length of the electrical shocks they provided were used as measures of their aggressive behavior. In addition, their blood pressures and heart rate were measured before and after they played or watched the game or film. Results were as follows: (a) The participants of the game play condition provided longer shocks than those of the control group; (b) The participants of the game play condition provided stronger and longer shocks than those of the game watching group; and (c) These results were unchanged even when the mediating effects by blood pressure and heart rate were removed out. These findings suggest that violent video game use could develop human aggressiveness, and this development process would result from mere watching of violent images or physiological arousal.

3. Our Approach of VR Technology based on Sensory Substitute Study[6]

In order to substitute the lost or damaged senses, the purpose of sensory substitute studies is to create images which are similar to original sensations by transmitting information to the central nervous system through the residual senses or through the nervous systems. On the other hand, VR is one of the technologies that can display information which is similar to real images. This research approach is almost the same as the sensory substitute studies except that the sensory substitute devices are used only by the disabled.

We have been carrying out the sensory substitute studies for about 25 years, and have designed several substitute devices which are in practical use or will be put into use. Furthermore, we have obtained many findings regarding sensory integration, concept formation, and sensory-motor association in the human brain. We will refer to our research regarding the sensory substitutes and mention how it relates to VR research.

Through fundamental research on auditory and tactile information processing, about 20 years ago we developed a tactile voice coder for the deaf which produces sound spectral patterns. These patterns are analyzed in 16 frequency components to an index fingertip by using a piezo-electric vibrator array consisting of 16 rows by three columns as shown in figure 4.

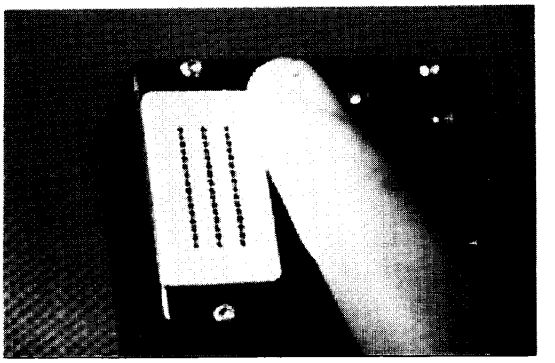

Fig.4 Avibrator array for tactile voice coder

We are now improving the tactile voice coder using a digital signal processor (DSP) to make it smaller and cheaper. The findings and technologies regarding the tactile voice coder will be applied to a tactile display for VR systems. About 15 years ago, the tactile voice coder was applied to a voice typewriter for acquired-deaf people for whom it is difficult to learn lip-reading and sign language. This device can convert monosyllabic voice sounds such as /a/ /ka/ /sa/ /ta/ /na/ /ha/ into Japanese letters almost in real time and shows them on a display. It can also be used as a typewriter for the upper-limb disabled. The voice typewriter was manufactured and applied to the input device of a Japanese word processor. This technology will play an important role in interactive VR systems.

The author has been studying auditory prostheses which stimulate surviving auditory nerves of the deaf who have lost the function of hair cell receptors inside the cochlea. At Stanford University, the author conducted the study of auditory prostheses about 12 years ago. In our auditory prosthesis, auditory nerve cells are electrically stimulated by 8 electrodes placed in the cochlea. Spectral patterns were analyzed in 8 steps. The 8 signals were transmitted electro-magnetically from a transmitter outside the body to a receiver inside the body. Although our method was not so effective for recognition of speech, especially consonants, we have acquired some findings regarding sensory association in the human brain. These findings will be related to creating an association between VR and the real world.

In general, elderly people who have suffered from a hearing impairment have less ability to understand spoken language even though they can hear the speech sounds. This phenomenon seems to be due to a decrease in the recognition of auditory time patterns in the speech area of the cortex. Therefore, in cooperation with the Hitachi

company, we have designed a hearing aid which can slow down speech without any pitch frequency change by using a digital signal processor as shown in figure 5.

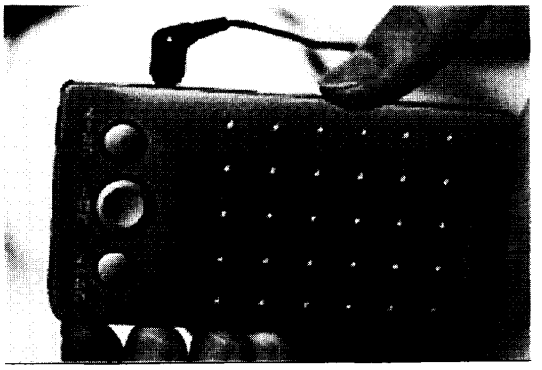

Fig.5 Digital hearing aid with a speech rate converter

We have proved that the device is effective in catching the meaning of rapidly spoken sentences for the elderly sensorineural hearing impaired. Facilitating speech comprehension will become important in order to construct VR systems for the elderly.

Various methods for vocal rehabilitation have been applied for laryngectomees who have lost their speech function. We have studied the vocalization mechanism of a mynah bird, which can imitate human voices, in order to apply it to a synthetic sound generator for laryngectomees. From the analysis of the mynah's vocalization mechanism, we found the mynah can clearly imitate phonetic information such as intonation and accent. In order to improve a conventional electric artificial larynx, we have proposed a new method that can allow laryngectomees to control intonation by using their respiration. The device consists of three parts as shown in figure 6.

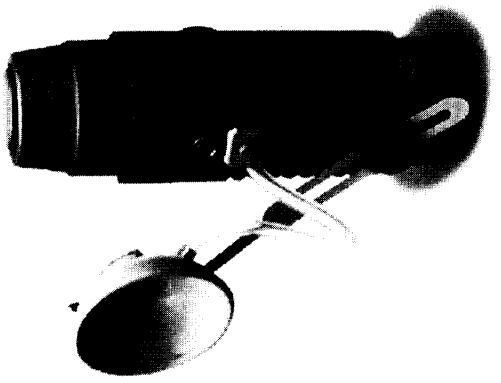

Fig. 6 Electric artficial larynx with a pich control function

By using the optimal parameters, the pitch pattern of the electric larynx voice becomes clearly similar to the pattern produced by a normal subject after one day of training. It has been proven that intonation is very important to make an artificial larynx voice natural. This finding is concerned with speech synthesis used in VR systems.

A new model of a mobility aid for the blind has been developed using a microprocessor and ultrasonic devices. In this model, a down swept frequency modulated ultrasound is emitted from a transmitter with broad directional characteristics in order to detect obstacles as shown in figure 7.

Fig.7 Ultrasonic eye glasses for the blind

However, most of the blind people can detect obstacles without these devices. This ability is called the "obstacle sense". Figure 8 shows two steps of obstacle sense: first perception and final appraisal.

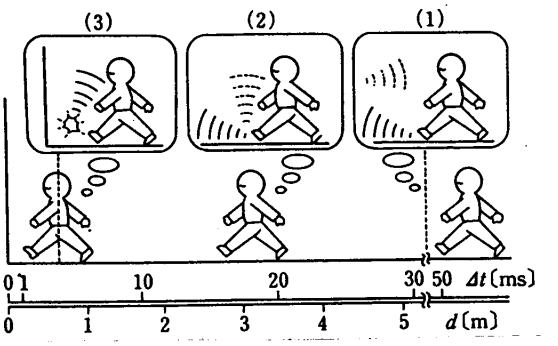

Fig. 8 Two steps of obstacle sense: (2) and (3)

We have been investigating the mechanism of the obstacle sense based on psychophysical experiments using blind students. We have found the reason why the blind can detect the obstacle is that they can discriminate the tiny difference in the sound field when an obstacle is present and not present. We are intending to design a mobility aid device which uses the ability of the obstacle sense. Furthermore, we could make the blind hear "virtual obstacles" by controlling the sound field produced from a speaker array. This study has also been related to VR research.

We have designed a force display which will be able to be used for a VR system by using a metal hydride

(MH) actuator. Hydrogen absorbing alloys are capable of storing hydrogen gas up to the level of approximately 1000 times their own volume. By heating the alloy, hydrogen equilibrium pressure increases and hydrogen is emitted, whereas by cooling the alloy, hydrogen equilibrium pressure decreases and hydrogen is absorbed. A Peltier element is used as a heat source. The drive function using hydrogen absorption and desorption has a buffer effect and it prevents extreme power changes or shock. Thus, this MH actuator is not harmful to humans, making it suitable for use in equipment which is attached to humans. Figure 9 shows a force display in which two MH actuators are used.

Fig.9 Force display with two MH actuators

We have also developed a transfer aid for the disabled using an MH actuator with 40 g alloy in cooperation with a company as shown in figure 10.

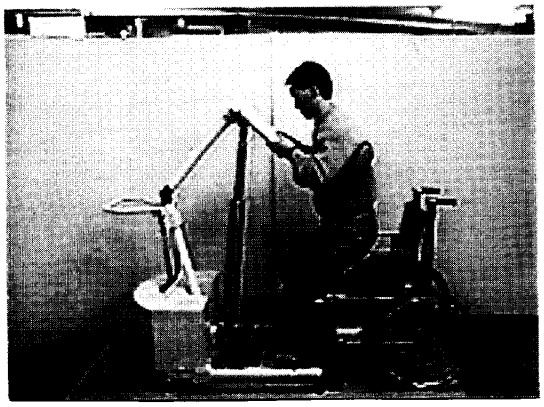

Fig.10 Transfer aid for with an MH actuator

A tele-existence system of the tactile sense was also designed for the sensory substitutes. Figure 11 shows a globe with joint angle sensors made of chip coils to detect the joint angles of human fingers with multiple joints used for a tele-exsistence system of the tactile sense. Characteristics of artificial skin attached to artificial fingers are based on the experimental results of force-displacement characteristics of the human skin. The sensations produced by the pressure and the strain applied to the fingertip surface were measured as functions of pressure force level and the direction of the strain force using psychophysical techniques.

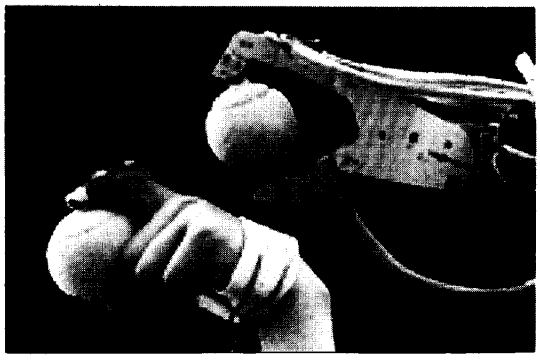

Fig. 11 Tele-existence system of the tactile sense

A study of pressure sense and a force vector display are useful from the viewpoint of the tele-existence system of the tactile sense.

Based on the above techniques and the findings, we have constructed a virtual reality system which consists of a head mount display, a speaker array, a rotational chair, and a sound proof room as shown in figure 12.

Fig. 12 Room with virtual reality system

The temperature of the room can be changed in the range from -4 degrees to plus 40 degrees. We are now investigating a mechanism of sensory integration. For example, we have investigated how the rotational stimulation influences the visual and auditory sensations. These kinds of findings will be useful to design both better models of VR systems and rehabilitation devices.

4. Research Project of Mixed Reality System

A research project of a mixed reality (MR) system has begun this year in order to construct a kind of augmented reality in cooperation with the ministry of international trade and industry, and Cannon company. MR is an integration between the real world and a virtual world. Information in reality and virtual reality is put together and

displayed. In order to create a smooth MR environment, a number of problems have to be dealt with. When looking from one place to another, an image separation occurs. We call this differential separation between the real world and the virtual world 'static registration error'. There is also a difference in image quality between reality and VR. We call this difference 'rendering registration error'. Another problem is that the image can not keep up when a human suddenly looks in a different direction. We call this 'dynamic registration error'.

We have been asked to evaluate how these errors influence the human body such as the visual function, the autonomic nervous system, and the sense of equilibrium. In order to investigate the influences, the Sapporo research branch was constructed. In the center, we have three rooms: (1) a control room in which there are some computers to create images and control equipment, (2) a display room in which an arch-screen (figure 13), a motion base with two force plates, a speaker array and a 3-D motion analysis system are settled, and (3) a bio-medical measurement room in which we can measure the visual function, the autonomic nerve function and the sense of equilibrium using several equipment such as a ref-keratometer, a tonometer, an accommodometer, topo-EEG, etc.

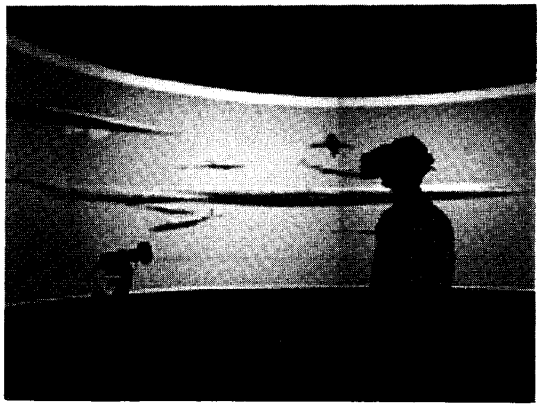

Fig. 13 Arch-screen in a display room of MR system co.

We are planning to investigate how sensory integration is formed in the human brain when different stimulations such as the visual and the balance stimulations are displayed simultaneously or successively. The findings that will be obtained from the research project of MR will be useful to create a better VR system.

5. Conclusion

As mentioned above, I first refered to the evaluation of VR which was done by one of 4 research groups involved in the basic study of VR supported by the Japanese Ministry of Education (Science and Culture Grant-in-Aid for Scientific Research). The results obtained from the above study are as follows: (1) Concrete results were obtained from a medical application which could facilitate neurosurgical intervention by using the volumegraph, (2) HMD stimulation on far peripheral vision may cause motion sickness, (3) an interactive educational game utilizing an audio virtual system may improve blind students' audio localization skills, (4) in the study of auditory processing of concurrent sounds using a SQUID, segregated auditory streams representing concurrent sounds are spatially mapped within the auditory cortex, (5) from the analysis of the subjective reports obtained from high school students who played VR games, it would appear that cognitive properties could exert an influence at the cognitive level, although video games have little influence on personality per se, and (6) violent video game use could develop human aggressiveness, even though such aggressive behavior would not result from the mere watching of violent images or physiological arousal. These findings will be useful for designing better models of VR systems in the near future. However, a concrete evaluation of VR within society has not yet been obtained, thereby suggesting the need for a longer period of investigation to answer this question how VR system influences on society.

Additionally, I have suggested that the basic findings concerning human senses and the substitute devices for the disabled will play an important role in constructing VR systems and artificial senses for robots. Lastly, a research project of mixed reality was introduced. This project will also contribute to the clarification of the influence of VR stimulation on the human body.

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