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POSSIBILITY OF VIRTUAL REALITY FOR MENTAL CARE

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Abstract. The possibility of applying Virtual Reality (VR) techniques to the mental care of patients is discussed in this chapter. VR technology holds much promise for providing supportive activities and promoting cooperation among caregivers. Interactivity with media may give the feeling of control to patients and thus provide a greater joy than passively watching television. Immersion in VR is expected to reduce pain and relieve anxieties for a while. Some kinds of VR content would make patients relaxed or encourage them in their fight against disease. Moreover, networked VR could offer a virtual space where patients meet, communicate, organize activities, and share experiences with other people - other patients, friends, family members, medical doctors, social workers, and so on. A basic study and trials to evaluate our developed VR system, called the 'Bedside Wellness System,' provide evidence for the effectiveness of this approach. Future research tasks are also discussed.

1. Introduction

Various stressors can destabilize the mental states of hospital patients. These people typically engage in arduous battle against disease by submitting to daily examinations, operations and treatment. They suffer from pain and other symptoms. They are anxious about their present condition and diagnosis as well as future prognoses. A sudden illness can destroy their life plans, so they normally need some time and support to accept the situation. Long-term hospitalization shuts off patients from the outside world. It deprives them of their work, social activities, happy times with their families and their hobbies. Terminally ill patients suffer from the fear of death, anxiety over even greater pain and increased financial burden, and worry about the future of their families.

Such instability in mental states can break the physical homeostasis, which could lead to physical and psychological problems [1]. Therefore, mental care for bedridden patients is an important challenge for the medical establishment. Cooperation among medical doctors from various specialties, co-medical and para-medical workers, and the patient's family is essential to support patients.

In addition, new kinds of facilities that provide supportive activities and promote cooperation among caregivers are necessary. Virtual reality (VR) technology holds much promise for realizing this kind of facility. Interactivity with media may give the feeling of control to patients and thus provide a greater joy than passively watching television. It can produce simulated experiences of the real world that satisfy to some extent the desire to go out and experience the outer world. Immersion in VR is expected to reduce pain and relieve anxieties for a while. Some kinds of VR content would make patients relaxed or encourage them in their fight against disease. Networked VR could offer a virtual space where patients meet, communicate, organize activities, and share experiences with other people-other patients, friends, family members, medical doctors, social workers, and so on. It can also be utilized for team medication.

In this chapter we introduce our trial activities in using VR to reduce stress levels of patients. The results of a basic experiment showed evidence of VR's effectiveness; the VR system we developed for the above purpose worked well with normal subjects, and its application to cancer patients has already begun.

2. Preliminary results for VR effectiveness

2.1 Experiment

A basic study was conducted to investigate the possibility of using VR to reduce stress levels [2,3]. Ten healthy male adults on no medication, aged between 30 and 35, participated as subjects. The experiment was conducted at the National Cancer Center Hospital and used its VR system. This VR system consisted of two ONYX Reality Engines (SGI) and a 100-inch projector (Fig. 1). Two kinds of VR sessions were presented to the subjects: a driving simulation in a country town and a flight simulation over mountains. Both sessions were made by computer graphics. A mouse was used as a tool for interaction through which the subjects could control the direction and speed of moving in the virtual world. Easy listening music was also provided to allow the subjects to better enjoy the experience during their drive or flight. A pain thermometer (Unique Medical, UDH-104) was introduced to give thermal pain as a source of stress to the normal subjects and also, as a probe stimulus, to see how much they became immersed in VR.

The thermal pain threshold temperature (THT) was defined as the temperature where the subjects began to feel pain. To obtain the autonomic indices, which are influenced by the mental state of subjects [4], chest electrocardiogram and respiratory movements were measured during the resting states and VR sessions. The subjective ratings were obtained from a questionnaire of eighteen adjectives describing emotional states measured by a categorical rating scale of five ranks.

2.2 Results

A rise in THT was recorded during VR sessions, suggesting that the subjects were so absorbed in VR that it took them a longer time to become aware of the pain (Fig. 2). The mean heart rate (HR) decreased for nine subjects during the VR sessions compared to the resting states, while the remaining one subject, who experienced a strong sickness to VR, showed a rise (Fig. 3). The amplitude of the respiration and its frequency increased slightly during VR. The indices for heart rate variability and respiratory irregularity did not show consistent changes. These results suggested that sympathetic withdrawal was caused by the VR for the nine subjects who did not experience sickness. Physiological changes suggested that the state caused by VR differed from relaxation; it can be thought of as «active comfort» .

***Figure 1**. Experimental settings for basic study*

For the same nine subjects, the subjective ratings of the VR sessions for positive emotions such as ‘vivid’, ‘absorbed’ ‘interested’, ‘pleasant’ and ‘excited’ increased, and those for negative emotions such as ‘tired’ and ‘absent’ decreased. On the other hand, the subject who had a strong sickness reaction to VR showed a reduction in positive emotional scores and an increase in negative ones (Fig. 4).

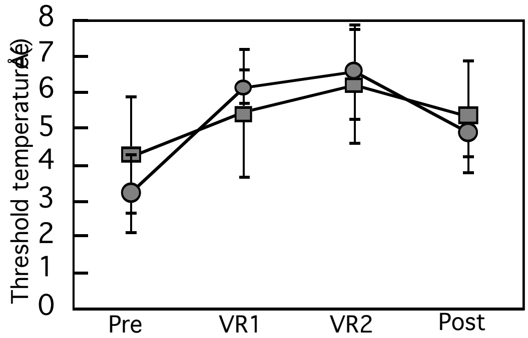

Figure 2. *THT changes caused by VR in basic study*
squares: subjects without VR sickness(N=9), circles: a subject with VR sickness

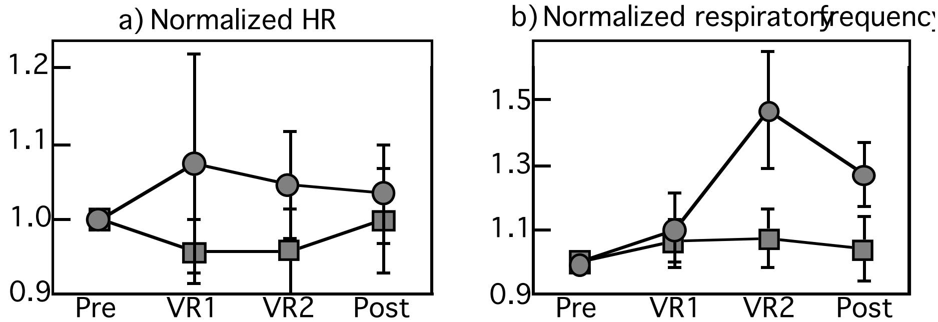

Figure 3. *Physiological changes caused by VR in basic study*
squares: subjects without VR sickness(N=9), circles: a subject with VR sickness

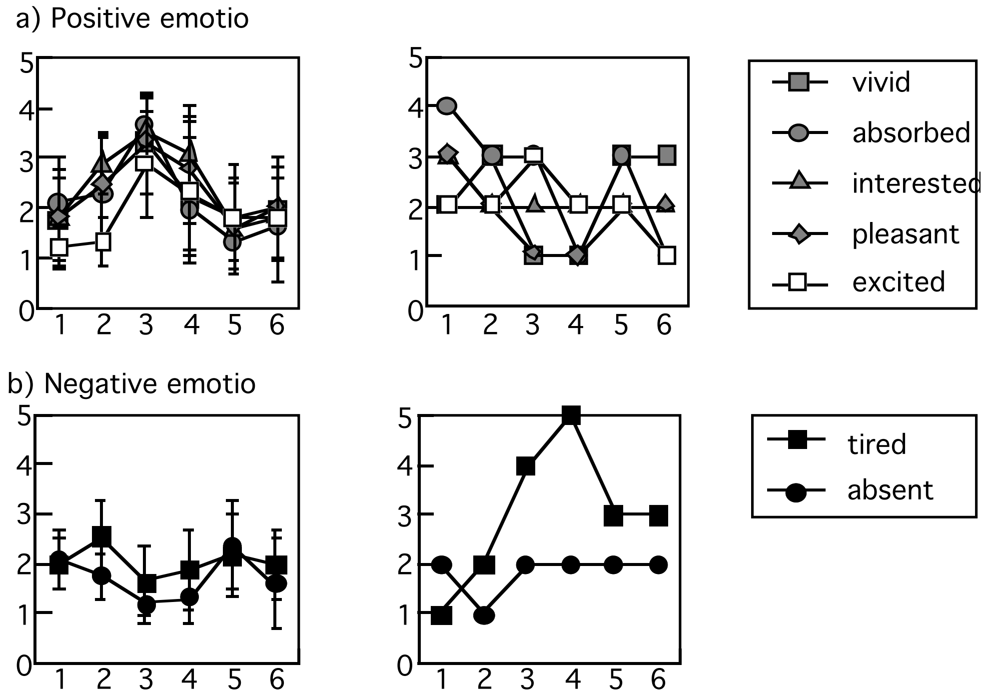

Figure 4. *Emotional changes caused by VR in basic study*
left: results for nine subjects without VR sickness, right: results of one subject with VR sickness

For the subject who felt sickness, HR elevation was caused by sympathetic activation, as reported in previous literature [5]. Therefore, we concluded that VR is helpful to reduce stress levels if careful consideration is given to designing VR so that it does not cause sickness.

3. Further trials using a new VR system

3.1 A new system concept

We proposed a system capable of producing a feeling of walking through a forest [3, 6]. Based on our belief in the healing power of nature, we selected a forest stroll as a virtual environment and used actual images of natural scenery.

The developed system is called "Bedside Wellness System", and it has the following four features: 1) it gives patients the impression of being in the natural world through not only sight but also sound, fragrance, and the feeling of a breeze brushing the skin; 2) it produces a more natural feeling of waking without causing VR sickness through the invention of a new method called "stepwise motion-pictures"; 3) it matches the patient's physical condition by using a foot device with variable torque patterns; and, 4) it uses a vital-sign unit and a subjective assessment tool to prevent overexertion and to assess the effects of the system on the patient.

Figure 5 shows the developed system. Wide-angle vision was achieved by using a three-screen liquid-crystal display, which gives the patient the impression of being present within the landscape. A 3D-sound system was also adopted, and it gives the chirping of birds and the flowing of a brook. Finally, a unit to deliver a scented breeze was developed, and it gives a gentle breeze brushing against the patient's face while carrying a refreshing fragrance of trees.

The key point of our "stepwise motion-pictures" method is the stepwise change of the viewpoint in sync with the patient's steps. This was achieved by decoding the compressed motion-pictures of individual viewpoints previously recorded and stored on a HD. The sound of footsteps was also designed to be triggered by the patient's steps. Gesture inputs using an artificial retina chip or mouse inputs enhance the patient's feeling of participation by allowing him or her to choose the route at path junctions.

Figure 5. *Bedside Wellness System*

Foot devices that could be precisely controlled by a servo mechanism were then developed. The interface was designed to enable easy setting of the foot device's torque patterns to match the patient's physical condition. A movement-assistance mode was also achieved.

A vital-sign unit was introduced to monitor such conditions as electrocardiogram, blood pressure, and respiration to prevent overexertion and to assess the total effect of the system on the patient; the data from this unit is then later used to improve the training program. A simple tool for subjective assessment was also developed using a hand-held computer with a pen input.

3.2 Assessment of the developed system

We conducted an experiment to investigate the efficacy of the system by testing it on healthy subjects at the National Cancer Center before using it with actual patients [3,6]. Twenty-seven subjects aged between 19 and 51 participated in the experiment. Nineteen of them were male; eighteen were medical doctors and one was a physical trainer, who were expected to give expert comments on the potential and drawbacks of the system from clinical viewpoints. The female subjects were secretaries, assistants and a student.

Two experimental sessions were conducted. Each session was composed of a three-minute rest trial and a subsequent five-minute system trial. Two experimental conditions for the system trials were introduced: one with all functions of the system ('VR') and the other with only the foot devices without the virtual environment stimuli such as images, sound and smell ('without VR'). The order of the conditions was counter-balanced among the subjects.

The pain thermometer introduced in the basic study was again used to give thermal pain as a source of stress to the healthy test subjects and as a probe stimulus to see how deeply they were immersed in VR. The thermal pain threshold temperature (THT) was measured once a minute during each trial. Chest electrocardiogram and respiratory movements were also measured. In addition, blood pressure was continuously measured at the radial artery by a tonometry method (Nihon Colin, SA-250).

Immediately after each trial, an observer who was not informed of the condition of the previous trial entered the room to assess the subject's emotional state with a questionnaire listing nine adjectives, each judged on a scale of five ranks. After each observation, subjective ratings were also obtained from the subject orally by using a similar set of adjectives: 'relaxed', 'refreshed', 'calm', 'vivid', 'tensed', 'depressed', 'unpleasant', 'sleepy' and 'tired'. After finishing all trials, the subjects were required to answer a written questionnaire on both the positive effects (relaxation, refreshment, enjoyment, immersion) and the negative ones (fatigue, pain) of each system trial. The questionnaire also asked for suggestions on points to be improved before introducing the system for clinical use as well as points to be considered in selecting patients and in applying the system to patients.

3.3 Results of experiment using developed system

Most of the subjects reported positive effects for the 'VR' trial, and fewer subjects did so for the 'without VR' trial (Table 1). Concerning the negative effects, fatigue on the lower extremities (legs, calf, ankles, and knees) was reported by seven subjects for the 'VR' trial and eight for the 'without VR' trial.

Table 1. Assessment of developed system by questionnaire

	with VR	without VR
relaxation	18	8
refreshment	13	3
enjoyment	21	12
immersion	11	5

Also, pain in the sole of the foot or in the knees was reported by one subject in each trial. No one reported fatigue or pain in other organs such as the eyes or ears. Furthermore, no complaint of VR sickness was reported.

The results of the questionnaire on suggestions for improvement revealed the need to improve the foot devices. The problems indicated by the subjects could be divided into two categories: one concerning the device structure and the other concerning the means of control. The discrepancy between the right and left devices and their excessive height seemed to cause fatigue to the lower extremities. Subjects reported that the movement and torque patterns should be improved to provide a more natural feeling of walking. Regarding the "stepwise motion-picture" method, the subjects requested a more continuous feeling of movement in future versions. They also desired a larger display if possible. The sounds of the birds and brook were well received. Individual differences were found in sensitivity to the fragrance and in preferred loudness of the virtual footsteps.

The obtained THT data, subjective ratings and physiological indices were studied for only the male subjects. The ages of the subjects considered were between 28 and 43, and they numbered twelve because three were omitted due to ongoing medication, one due to being too sensitive to the fragrance, and three due to missing data in some indices.

Contrary to our expectations, the THT data did not show any differences between the rest and system trials. This suggested that the interactivity was insufficient for full immersion compared to the earlier basic study, where continuous manipulation was linked to change in the virtual environment.

To obtain the subjective ratings, the effect of using the system and the existence of VR were examined by a 2 (session order) x 2 ('rest' vs. 'system') x 2 ('VR' vs. 'without VR') ANOVA. Figure 6 shows the results of indices that exhibit significant differences. An increase in the scores of 'refreshed' was observed by using the system with 'VR'; however, a decrease was seen by using it 'without VR'. The scores in 'vivid' showed a similar tendency but no significance. The scores of 'sleepy' decreased when using the system. The scores of 'tired' were lower in the 'VR' session than in the 'without VR' session. Moreover, no significant difference was found in the other ratings. It can therefore be concluded that the system has the effect of arousal from exercising the legs, and 'VR' has the effect of refreshment and reducing fatigue.

The changes in the ratings by the observer were occasionally contrary to those of the subjects. The extreme values and the patterns for some adjectives such as 'vivid' and 'tensed' were often similar, while those for 'sleepy' and 'tired' were nearly always different. We introduced the ratings of an observer in order to investigate the possibility of assessment by the facial expressions of patients; however, the results showed this to be in fact very difficult.

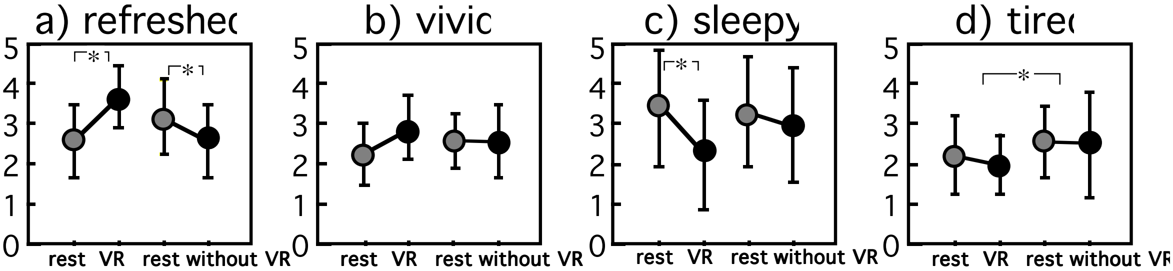

Figure 6. *Changes in subjective ratings caused by developed system*

Figure 7 shows the changes in heart rate (HR), the respiratory component of heart rate variability (RSA), and respiratory frequency (RSPF) during the system trials and during a 30-second recovery period. HR acceleration, RSA reduction, and RSPF elevation during the system trials were observed. These changes may have been primarily caused by exercising the legs. For half of the subjects, some problems appeared in the blood pressure (BP) measurements. Frequent calibration was done automatically with the cuff pressure induced on the upper arm, which may have resulted in a negative effect.

The subjects without such problems showed no significant changes in BP. A difference between sessions was observed only in HR. In addition, the above three indices recovered faster after the 'VR' trial than the 'without VR' trial during the post period. However, there is one problem with concluding that the system affected the reduction of sympathetic activation. Specifically, there is a difference in the quantity of movement between the two conditions: nine of the twelve subjects moved their legs more frequently during the 'without VR' trial. The mean intervals between footsteps during the 'VR' and 'without VR' trials were 3.61 and 3.17 seconds, respectively. This difference in the frequency of footsteps may represent the effect of VR on immersion, which should be confirmed in a future study.

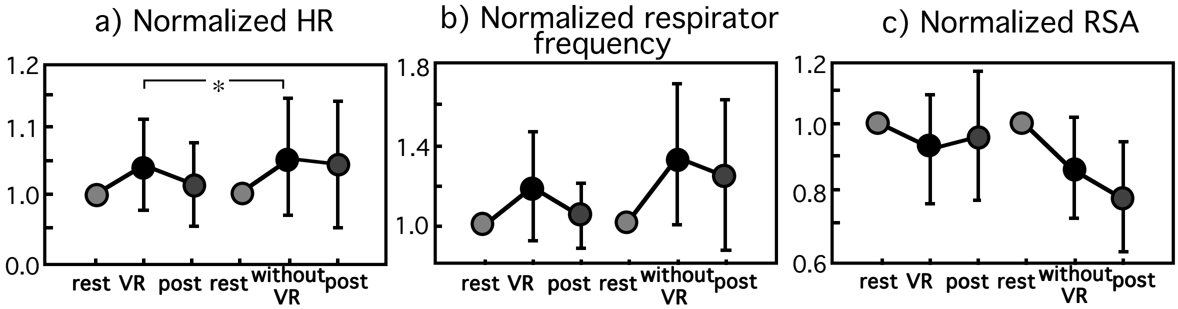

Figure 7. *Changes in physiological indices caused by developed system*

3.4 Improvements to the system

The experiments using healthy subjects suggested that the developed system will help patients relax and become refreshed, and that VR may increase positive effects such as enjoyment and immersion in a pleasant feeling. We decided to apply the developed system to cancer patients after making some improvements. The Wellness Business Development Center of Mitsubishi Electric Corporation and Mitsubishi Electric Engineering Nagoya cooperated in the development of a practical version of the bedside wellness system (Fig. 8).

Figure 8. *Improved Bedside Wellness System*

They achieved the following improvements:

1) the system became more compact for carrying and use in a private ward;
2) the structure of the foot devices was redesigned to minimize fatigue, and a method of control was developed to provide a more natural feeling of walking;
3) a variety of virtual environments in addition to the 'forest walk' was prepared;
4) additional functions to enable patients to enjoy Internet services and video tapes were supplied;

5) the system operation became easier for nurses and patients to adjust the preferred loudness, balance of the different kinds of sounds, and selection of a favorite fragrance in order to make the system optimally customizable to individual needs.

3.5 Clinical application of the system

The study team of the National Cancer Center Hospital began clinical application of the system to cancer patients. Cancer pain is a major source of psychological stress for patients. It sometimes causes disturbed sleep and makes the patient feel anxiety, fear, depression and loneliness. If cancer pain can be controlled by drugs, the patient's mental state will improve to allow the patient to get enough sleep, be relaxed and enjoy a social and spiritual life. The bedside wellness system is expected to help patients be relaxed and turn their consciousness away from the pain. It is also expected that the beautiful scenery with winds, scents, and sounds will make patients feel refreshed and that the fluctuations of a natural world will make them relaxed.

In the first stage, breast cancer patients with comparatively better performance states (ECOG Performance States 1 and 2) are being studied. Patients are screened for appropriate characteristics, and the treatments are conducted after getting informed consent. The changes in subjective assessment of their own mental state by questionnaire with five ranks and a visual analog scale are being investigated. The patients are asked if they look forward to repeated trials, to what extent they expect a positive effect, what kind of scenery they desire to experience, and so on.

We have not acquired a sufficient number of cases to confirm effectiveness; however, almost all patients were delighted at the treatment, conveyed positive impressions of the effects and expressed their hope to be treated again. Some patients reported a reduction in chronic pain during the trial. Some answered specific scenes they want to visit with the VR system.

3.6 Future possibilities of the developed system

Networking technology can provide a virtual environment, as discussed in the introduction. Social support is one of the most important factors in coping with stress. In the future, we would like to extend the bedside wellness system to a multi-user system connected to a network. This would provide a virtual world where patients can meet and chat with their family and friends and share experiences.

Biofeedback is an alternative method for mental care [1,7]. Patients can acquire the ability to control their mental state through biofeedback training. Biofeedback instruments measure the patient's physiological indices, estimate the patient's state, generate the feedback signals according to the patient's state, and present information to the patient with visual or auditory signals. Patients will become aware of how to improve their state by utilizing the information given by the instruments. Since the basic concept of biofeedback is self-regulation, the effectiveness of such therapy depends on the motivation of the patient. If only an attractive symbol such as a rocket is used as an alternative to a simple circle in the visual feedback, this may result in the improvement of the patient's motivation.

Using VR technology, we can produce more attractive feedback signals. The developed system can be used as a biofeedback instrument if we vary VR content according to the patient's state estimated by the measured vital signals. Furthermore, the ultimate style of system usage is expected to be a fusion of optimized VR and biofeedback. The presented virtual environments should be varied optimally in accordance with the patient's state so as to guide it in a better direction without the patient's effort. At the same time, the changes in the VR content can be the feedback signal if the patient prefers to make the effort to utilize it for self-regulation.

4. Conclusion and discussion

We showed the potential of VR technology for the mental care of hospital patients; however, we still need to improve the VR technology itself and investigate how to utilize it most effectively. It is essential to develop VR technology capable of constructing virtual but realistic environments that are enjoyable for patients without causing extra stress or fatigue. VR sickness, which was observed in the basic experiment, is also a major problem to solve. We assume that the requirements for reality in VR for mental care is different from those of a VR simulator for training. Development based on such an existing model should not be pursued if it causes VR sickness. The "stepwise motion-pictures" method is proposed as one alternative to existing VR approaches. The reality in feeling is important in spite of knowing the presented experiences are virtual and being aware of the differences from the real world. This perspective is similar to the case of art.

Acknowledgments

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