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Physiological Monitoring as an Objective Tool in Virtual Reality Therapy

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ABSTRACT

The goals of this study were twofold: (1) to investigate nonphobics' and phobics' physiological response in virtual environments, and (2) to analyze the trend of phobics' physiology during virtual reality (VR) treatment. As a measure of physiology, heart rate, skin resistance, and skin temperature were acquired. The data for two groups of participants were analyzed: 22 nonphobic participants (mean = 32 ± 9.4 years) and 36 subjects with fear of flying (mean = 40 ± 12.1 years) who met the DSM-IV criteria for fear of flying. As a result, skin resistance showed significant differences between nonphobics and phobics, $T(56) = 2.978$ and $p < 0.01$, respectively. The physiological response of 33 phobic participants, who were able to fly without medicine after VR treatment, showed a gradual trend toward the nonphobics' physiological responses as therapy sessions progressed. In this study, physiological monitoring, in particular skin resistance, appeared to be useful both in understanding the physiological state of phobic individuals and in evaluating the results of treatment in VR psychotherapy.

INTRODUCTION

Virtual reality (VR) technology has recently attracted much attention in clinical medicine. Given the new opportunities offered by this technology, several studies have been successfully conducted using VR for graded-exposure therapy, especially in the treatment of phobias.[1–8] Most of these studies relied on the individual's subjective feeling of distress for evaluating anxiety level by using subjective units of distress (SUDs) or self-report questionnaires. While analyses of SUDs or self-report questionnaires may elucidate the phenomenology of experiences, they remain subjective, and posttest measures are dependent on the memory of an event. According to Lang's 1985 proposal, anxiety assessment should include subjective and objective measures. He also stated that the motor program of fear (as evidenced by physiological arousal) must be activated in order to change the person's fear structure and have resulting behavioral change.[9] A few researchers, therefore, have tried to objectively measure anxiety and stress responses in real time by using physiological response such as heart rate, respiration rate, skin resistance, skin temperature, and peripheral brain wave EEG activity in virtual environments.[10–13] Wiederhold et al. found differences between the phobic's physiological responses and nonphobics' responses when placed in a virtual flying environment related to their phobia.[10] Meehan found a high and significant correlation between presence and skin conductance level with 10 nonphobic

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participants in virtual room environments.[11] Stoermer et al. showed heart rate variability was a powerful and easy-to-use instrument for monitoring the user's stress level.[12]

While these studies all showed the necessity of monitoring user's psychophysiological states in VR psychotherapy, they did not find a systematic relationship between nonphobics' and phobics' physiological response to virtual environments. The purposes of the study, therefore, were twofold. One was to investigate the differences between nonphobics' and phobics' physiological responses in virtual environments. And the other was to analyze the changes that occur in phobics' physiology as VR treatment sessions progress and desensitization occurs.

MATERIALS AND METHODS

Participants

Twenty-two nonphobic participants (mean = 32 ± 9.4 years) were recruited through local newspaper advertisements. Thirty-six participants with fear of flying (mean = 40 ± 12.1 years) who came to the Virtual Reality Medical Center (VRMC) for treatment were recruited for the study. Phobic participants met the DSM-IV criteria for a specific phobia. Table 1 shows demographic characteristics of participants.

Apparatus

The virtual environment system for this study consisted of a head-mounted display (MRG4, Liquid Image Inc., Toronto, Ontario, Canada), electromagnetic head tracker (INSIDETRAK, Polhemus Inc., Toronto, Ontario, Canada) and flight seat with subwoofer that delivered vibration to the subjects. It was designed by Drs. Hodges and Rothbaum of Virtually Better, Inc. (Atlanta, GA) who previously performed VR treatment for acrophobia and fear of flying.[1,5]

TABLE 1. DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

	Nonphobic	*Phobic*
Total		
n	22	36
Gender		
Male/female	10/12	14/22
%	45/55	39/61
Age (years)		
Mean	32.0	40
SD	9.4	12.1
Range	18–51	20–73

Physiological measures

Skin resistance (SR) was measured to determine changes in sweat gland activity. SR generally decreases as sweat gland activity increases. SR was monitored with two silver/silver chloride electrodes placed on the ring and index fingers of the left hand. For heart rate (HR), a small amount of electrode gel was placed on each disposable electrode attached to the participant's right and left wrist. Temperature was measured by a thermistor attached to the middle finger of the participant's right hand with cloth tape. An I-330 C-2 computerized biofeedback system manufactured by J&J Engineering (Poulsbo, WA) was used to collect physiological data. For phobic participants, the Subjective Units of Distress Scale (SUDS) was administered. It is used to rate anxiety on a scale from 0 to 100, with 0 being no anxiety and 100 being the most anxiety they have ever felt.

Procedures

Nonphobic. After signing an informed consent, a 5-min eyes-open baseline was taken. The participant then was placed in the MRG4 head-mounted display. The participant was allowed to look around the virtual plane to become oriented for a short while before the 20-min exposure began. The participant wore a head-mounted display and viewed a three-dimensional computer-generated image of the following flying scenes: sitting in the passenger cabin of a plane with the engines on, taxiing, taking off, flying in good weather, flying in bad weather, and landing.

Phobic participants. Phobic participants were all given the following protocol:

- *Session 1*: All treatment procedures and their rationale were explained, and informed

consent for treatment was obtained. The patient was given an intake to assess for seizure history, heart problems, and medication usage.

- *Session 2*: All participants were taught relaxation and diaphragmatic breathing skills, with the use of visual feedback of heart rate and respiration rate, prior to beginning the VR exposure therapy.
- *Sessions 3–8*: Participants were placed in a VR environment after an initial 5-min baseline of diaphragmatic breathing. The VR world was progressed to more and more difficult scenarios as the patient was able to maintain physiological control. At every step, the therapist could see and hear what the client was experiencing in the virtual plane. If the participant's level of anxiety became overwhelming, participants returned to a less stressful level of treatment, or simply removed the head-mounted display and exited the virtual aircraft.

Analysis

The percentage change from baseline was used for analyses rather than absolute values because physiology levels often vary widely by individual and environment. Therefore, before comparing physiology with presence measures, percentage change of heart rate (ΔHR) was calculated as follows:

$$\Delta HR = (MeanVR - MeanBaseline)/MeanBaseline$$

where MeanVR is the mean of heart rate during experiencing VR and MeanBaseline is the mean of Heart Rate during baseline.

Percentage change of skin temperature (ΔST) and percentage change of skin resistance (ΔSR) were also calculated using the same method. Data was analyzed using the conventional Student *t* test.[14]

RESULTS

The results of the conventional Student *t* test between nonphobics and phobics physiological responses in the virtual environment are shown in Table 2. Session data from the first exposure session for both phobics and nonphobics are used. At this point, phobics had learned diaphragmatic breathing, which nonphobic participants were not taught prior to exposure. The percentage change of skin resistance (ΔSR) showed significant differences between nonphobics and phobics, $T(56) = 2.978$, $p < 0.01$. Before the experiment, it was predicted that percentage change of heart rate would also show significant difference between the two groups, however, this difference did not occur. It is felt that more sensitive measures, such as analysis of heart rate variability, might show differences.

TABLE 2. STUDENT *T* TEST BETWEEN PHOBIC AND NONPHOBIC PARTICIPANTS

	t	*Significance (two-tailed)*
ΔHeart rate	−0.906	0.369
ΔSkin temperature	−1.042	0.302
ΔSkin resistance	2.978	0.004

After completion of treatment, 33 of the 36 phobic participants were able to fly without medication, indicating a success rate of 91.6%. Figure 1 illustrates the trend of ΔSR of nonphobic participants and "treatment-responder" phobic participants. Nonphobics showed physiological arousal at the beginning part of the virtual exposure, but by the end of the 20-min flight, physiology had actually stabilized and showed less arousal than at baseline, prior to the beginning of the virtual experience. According to previous research, repetition of a stimulus that is novel because of its unexpectedness reduces the information in the stimulus and, thus, the reaction is rapidly habituated.[15–17] Contrary to nonphobic participants, phobic participants still remain aroused throughout the first 20-min VR session. The physiological responses of the 33 phobic treatment responders, who successfully flew without medicine after VR treatment, showed a gradual trend toward the nonphobics' physiological responses as therapy sessions continued. This implies that desensitization, a treatment based on gradually and systematically exposing the phobic person to the feared

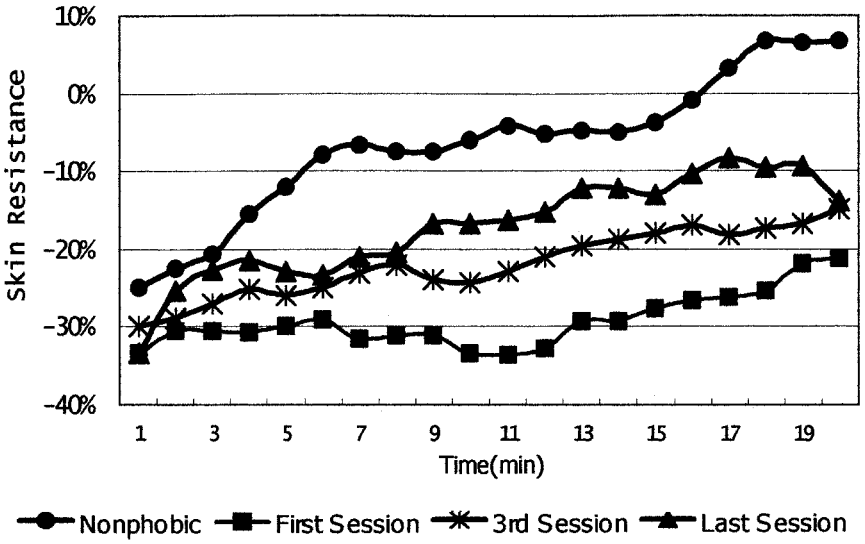

FIG. 1. The average change in skin resistance for nonphobic participants and phobics' 1st, 3rd, and last session who took a flight without medication following completion of treatment.

object or situation, and having them calm themselves in the anxious situation, was effective in the treatment of fear of flying using a virtual environment. It also proved the assertion of Foa and Kozak that, as treatment continues and habituation occurs, there should be a lessening of arousal.[18]

The physiological responses of the three treatment nonresponders who failed to fly after VR therapy are illustrated in Figure 2. The patterns appeared to be irregular and during the last session did not show any similarity to the nonphobic response. A comparison between the phobic responders and nonresponders is shown in Figure 3. The average SUDS and the average change of SR showed a decrease over treatment in the treatment responders, whereas those who were nonresponders showed less arousal physiologically for all sessions, but more SUDS as treatment progressed, indicating more subjective arousal. The fact that they responded less physiologically might

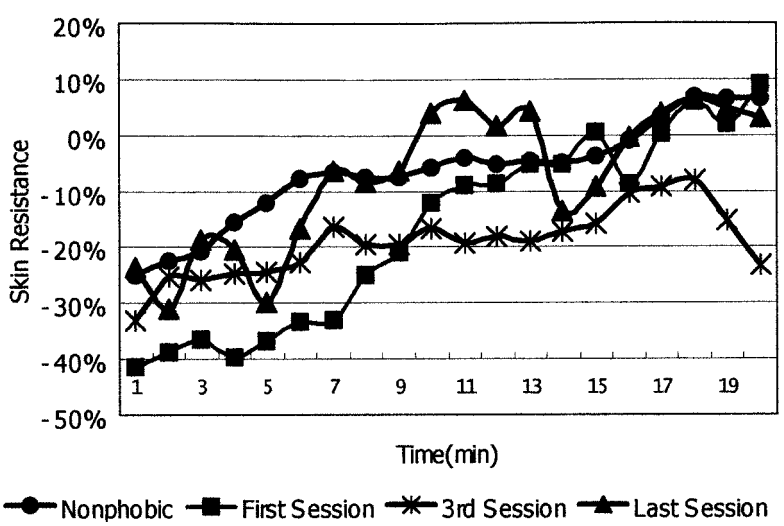

FIG. 2. The average change in skin resistance in nonphobic participants and phobics' 1st, 3rd, and last session who did not fly after treatment.

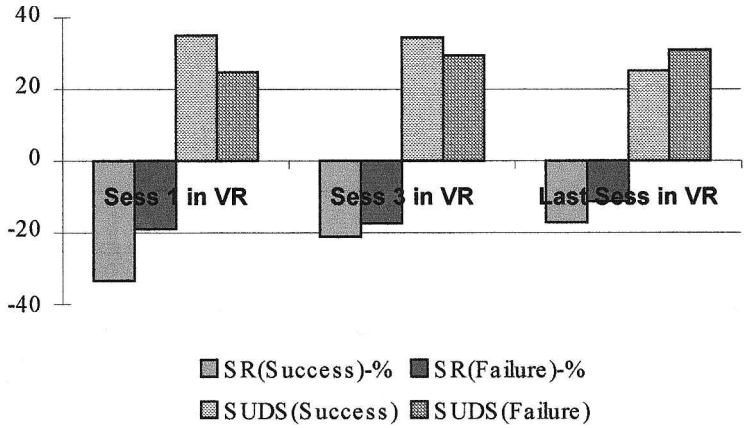

FIG. 3. The comparison between phobic treatment responders and nonresponders: average Subjective Units of Discomfort Scale (SUDS) and the average change in skin resistance (SR).

also indicate a lack of immersion, which led to a lack of desensitization.

CONCLUSION

In future studies, more systematic research should be performed to include more sensitive physiological measures, such as blood pressure and heart rate variability. It appears however that SR is clearly a sensitive and useful measure of treatment response and that physiological monitoring is a useful part of a phobic treatment protocol. Phobics do show a significantly different response than nonphobics when placed in the virtual world, and this difference tends to decrease over time as desensitization and habituation occur. Physiology appears to be a useful tool both in understanding the physiological state of phobic and nonphobic individuals and in evaluating the results of treatment in VR psychotherapy.

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