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THE EFFECTS OF IMMERSIVENESS ON PHYSIOLOGY

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Abstract. The effects of varying levels of immersion in virtual reality environments on participant's heart rate, respiration rate, peripheral skin temperature, and skin resistance levels were examined. Subjective reports of presence were also noted. Participants were presented with a virtual environment of an airplane flight both as seen from a two-dimensional computer screen and as seen from within a head-mounted display. Subjects were randomly assigned to different order of conditions presented, but all subjects received both conditions. Differences between the non-phobics' physiological responses and the phobic's response when placed in a virtual environment related to the phobia were noted. Also noted were changes in physiology based on degree of immersion.

1. Introduction

Some researchers note that "presence" or "being there" is what distinguishes virtual reality systems from other multimedia experiences. Even though users of the systems "know" they are not actually in the situation which the computer-generated world symbolizes, they subjectively report that they are "there" [1]. Maximal presence has been proposed as occurring when the user feels immersed in the environment, feels capable of interacting with the environment and has an interest in the environment or task portrayed [2]. In effect, presence involves feeling as though one is more a part of the computer-generated environment than the real world environment which he is physically located in [3].

Fontaine (1992) [4] proposed that users must focus their attention on the virtual world in order to subjectively feel present. They do not have to exclude of the real world but rather must direct their attention to the virtual environment. Unfortunately presence has been discussed often and systematically studied seldom [5].

2. Immersion and Involvement

Immersion is characterized by "perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences" [3]. Therefore, it is assumed that when one feels more "immersed", one will feel more present. A HMD provides more of this envelopment than a computer screen because the view and sound are total and unescapable. Involvement is another component thought to be important in establishing presence and is defined as the focusing of attention on a coherent set of stimuli, so that more focus of attention would lead to more involvement which would lead to more presence. Immersion and involvement have been proposed as being necessary to achieve presence [3].

3. Measuring Presence

By asking for self-report, by viewing overt behavior, and by recording objective physiological measures one can measure presence. Included in the behavioral category might be seeing a person turn away or close their eyes when presented with an anxiety-provoking scene. Included in the physiological category might be an increase in heart rate or sweat gland activity when viewing an anxiety-provoking scene. Self-report may be something as simple as asking the patient if they feel immersed in the computer-generated world or feel as if they are part of that world, or it may include Likert type rating scales, where a number (usually 1-7) is assigned to the experience or magnitude estimates where users indicate degree of presence (0 - 100%). Obviously, using all measures in combination is thought to be best [6]. Witmer & Singer [3] created the Presence Questionnaire and have found it to be reliable and valid, including such questions as, "How aware were you of events occurring in the real world around you?"

Heeter (1992) [7] described three types of presence: individual, social, and environmental. Individual might include preconceived assumptions the person brings to the experience, length of time spent in the virtual world, and familiarity with the environment represented in the experience. Social factors might include interaction with the participants by others in the virtual world and presence of other individuals in the virtual world. Environmental factors would include range of sensory modalities stimulated by the environment, pixel resolution, whether stereopsis is present, or absent, and whether the world is represented in color or in black and white.

Except for training with military simulators, physiological data has not been extensively correlated with the level of presence during anxiety-provoking stimuli in virtual worlds. We believe that physiological measures can augment and quantify the level of immersion and presence in virtual scenarios.

In the present study, participants were exposed to the same virtual environment but with two levels of immersion: either viewed through a head-mounted display or viewed on a two-dimensional computer screen. After both conditions were presented, the subjects were asked to indicate which condition produced a greater feeling of presence. It was predicted that a more immersive environment would increase presence and a more immersive environment due to the participant feeling more present would increase physiological arousal.

Further it was predicted that someone with a fear of flying, when exposed to a virtual environment depicting an airplane flight, would have more physiological arousal than someone without a fear of flying exposed to the same environment.

4 Method

4.1 Participants

The participants were two males and three females, one in his 40's and four in their late 20's. One participant had a fear of flying and met the DSM-IV criteria for a specific phobia. The other four participants had no fear of flying. Volunteers were recruited from doctoral-level classes at the California School of Professional Psychology, San Diego. Participants were tested within a one-month period. All participants reported never having been in a virtual reality experience prior to the experiment.

4.2 Basic Task

The task was to view an airplane flight as though sitting in the passenger cabin of an aircraft seated in the left window seat over the wing of the plane and looking out of the left window. The participants were seen for one session that included a 5-minute eyes closed baseline, 5-minute eyes open baseline, 10-minute flight viewed through the HMD, and 10-minute flight viewed seated in front of the computer screen. The view in both instances was exactly the same due to positioning of the HMD. During the "computer screen" condition, lights in the room were also turned off to give as much immersiveness to the condition as possible. After two physiological recordings were performed to obtain baseline physiology levels, one with eyes open, one with eyes closed, the flight began with the airplane sitting still on the runway with the engines on. The flight then progressed to a taxiing phase, a takeoff, a flight at altitude in good weather, and a landing experience. The flight was administered to three participants first on the computer screen and second in the head-mounted display. These included two persons without a fear of flying and one person with a fear of flying. The flight was administered to two of the participants first in the head-mounted display and then on the computer screen.

The current fear of flying system being used was designed by Drs. Hodges and Rothbaum of Virtually Better, Inc. (Atlanta, Georgia) who have previously performed VR treatment for acrophobia and fear of flying [8,13]. The system is run on a high-end Intel Processor-based personal computer and contains advanced audio and Diamond Monster-3D graphics cards, external multimedia speakers and subwoofer, a Polhemus INSIDETRAK position Tracker, and customized software. Audio was delivered to the participants through earphones on the HMD, or through speakers positioned next to the computer screen. Vibratory sensations were delivered via a subwoofer mounted under the participant's chair.

4.3 Experimental Design

The three factors in the 2 x 2 x 6 ANOVA with repeated measures design were 1) level of immersion (computer screen or HMD), 2) order of pairing (computer screen first, HMD second; or HMD first, computer screen second, and 3) eyes open baseline and flight sequence (engines on, taxi, takeoff, flying in good weather at altitude, and landing). Analyses reported were performed with SPSS 8.0 for Windows [30].

5. Measures

5.1 Self-Report Questionnaires

The following questionnaires were administered to all subjects:

- Questionnaire on Attitudes toward Flying (QAF) was used to assess flying history and attitudes as well as amount of fear caused by several aspects relating to flying. Scores may range from 0 to 360. Test-retest reliability has been reported at .92 [14].
- Fear of Flying Inventory (FFI) measures different aspects of flying and how much anxiety each causes, from none at all to very severe. Scores may range from 0 to 264. Test-retest reliability is reported at .92 [15].
- Self-Survey of Stress Responses (SSR) attempts to determine a person's pattern of physical responses to stress, whether it is autonomic, somatic motor, or central nervous system. An example of an autonomic response item is "My stomach flutters". An example of a somatic motor response item is "I tap my feet or fingers". And an example of a central nervous system response item is "I pick at things (lint, hair, etc.)". Items may be rated 0 to 5. There are 38 items to the scale [16].
- State-Trait Anxiety Inventory measures a person's situational (or state) anxiety as well as the amount of anxiety a person generally feels most of the time (trait). The two scales contain 20 items each, which may be scored 1 (not at all) to 4 (very much so). Trait anxiety has a reliability of .81 and state of .40, with internal consistency of between .83 and .92 [17].
- The Tellegen Absorption Scale (TAS) assesses a person's ability to become deeply absorbed into what one is doing or one's environment. Scores on the 34 item True/False inventory may range from 0-34 [18].
- The Hypnotic Induction Profile (HIP) determines hypnotic responsivity or how easily a person might become hypnotized [19]. The HIP scores may range from 0-16, with 0-5 meaning low hypnotizability, 6-10 being mid-range hypnotizability, and 11-16 meaning a person is likely to be highly hypnotizable.

5.2 Physiology

The following physiological parameters were measured:

Skin Resistance; which changes in relation to change in sweat gland activity-as sweat gland activity increases, skin resistance decreases; heart rate, measured by electrocardiography; peripheral skin temperature measured with a thermistor; and respiration rate measured with a pneumograph. Skin resistance was monitored with two silver/silver chloride electrodes placed on the ring and index fingers of the left hand. An I-330 C-2 computerized biofeedback system manufactured by J&J Engineering (Poulsbo, Washington) was used to collect physiological data.

6. Virtual Reality Exposure Therapy Procedure

After signing an informed consent and being given a brief intake to assess for seizure history, heart problems, and medication usage (which might affect physiology), a 5-minute eyes closed baseline was taken. Next, a 5-minute eyes open baseline was taken. The participant sat quietly in a chair and was instructed to try and stay as still as possible so that movement artifact would be lessened. The participant then was either placed in a MRG4 head-mounted display by Liquid Image (Canada) or was seated in front of a three-dimensional computer screen. Three participants (two non-phobics and one phobic) viewed the flight first in the head-mounted display and then in front of the computer screen. Two participants (both non-phobic)viewed the flight first in front of the computer screen and then in the head-mounted display. The participant was allowed to look around the virtual plane to become oriented for a short while before the flight began.

During the 10-minute VR flight with the HMD on, the participant was instructed to look out the left window during the entire flight. This was to insure that each participant was exposed to exactly the same stimuli. The participant wore a HMD 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, and landing. The HMD was positioned by the therapist so that during the “sitting in front of the computer screen” condition the subject also viewed the same scenes during the same flying conditions as the previous HMD condition. As soon as the last condition was finished, participants were asked the following two questions:

1. In which situation did you feel most like you were actually on an airplane flight?
2. In which situation did you feel least like you were sitting in an office?

Participants were then assessed for Hypnotizability and asked to fill out the questionnaires previously described.

7. Non-Phobic Results

Differences between a non-phobic’s physiological response and a phobic’s response when placed in a VR environment related to the phobia were noted. Also noted were changes in physiology based on degree of immersion. Since the virtual environment is a new and novel stimulus, it is expected that some physiological arousal would occur. However, after orientation, one would be expected to relax to baseline physiological levels. The research participants without a fear of flying were each placed in the virtual environment. During a five-minute eyes open baseline, average skin resistance levels were 66. When placed in the head-mounted display, a relatively new and novel stimulus, skin resistance levels dropped to 54 (a decrease of 19%) indicating some physiological arousal. Then as orientation to the stimulus occurred, physiological arousal decreased and skin resistance increased to above baseline levels. As the ten-minute virtual flight continued, increased physiological relaxation began to occur as evidenced by an increase in levels of skin resistance (58 at the end of the flight). Subjectively, relaxation also continued to occur as the participant realized the new and novel stimulus was not dangerous. (Figure 1) During the two-dimensional computer screen condition, theh participants without a fear of flying again experienced a slight decrease in skin resistance (3%) from baseline levels, but were quickly able to stabilize to baseline levels and become more physiologically relaxed during the flight than at baseline. At the end of the flight, skin resistance levels were 24% above baseline levels. Asked which condition they subjectively felt more present in, all four participants chose the HMD condition. They said they were able to become "absorbed" and "immersed" in the scenario.

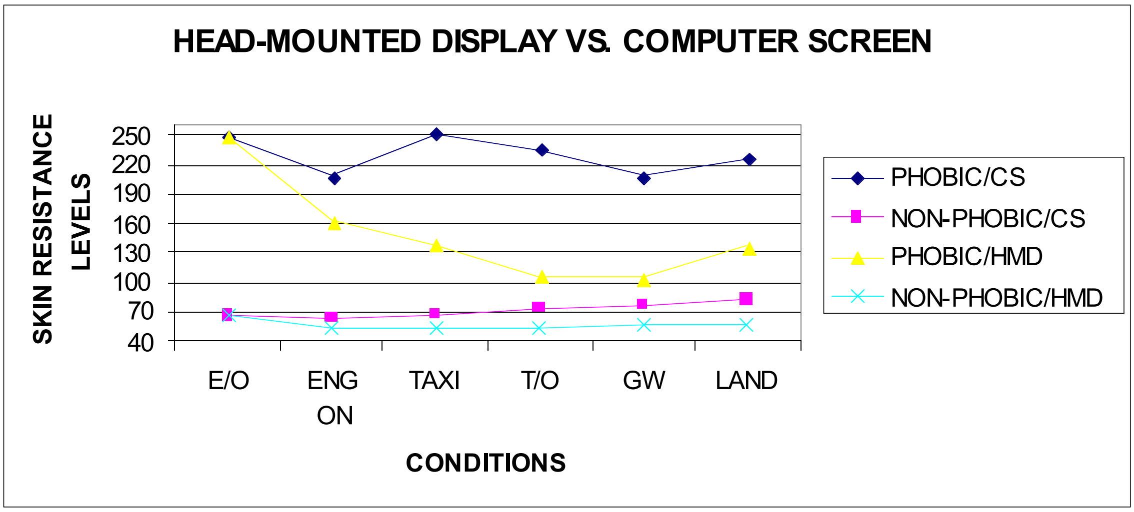

Figure 1. *Average skin resistance levels for four non-phobic participants and one participant with a fear of flying in computer screen (CS) and head-mounted display (HMD) conditions for eyes open baseline (E/O), and parts of a virtual flight: engines on (ENG ON), Taxi, Takeoff (T/O), Good weather (GW), and landing (LAND).*

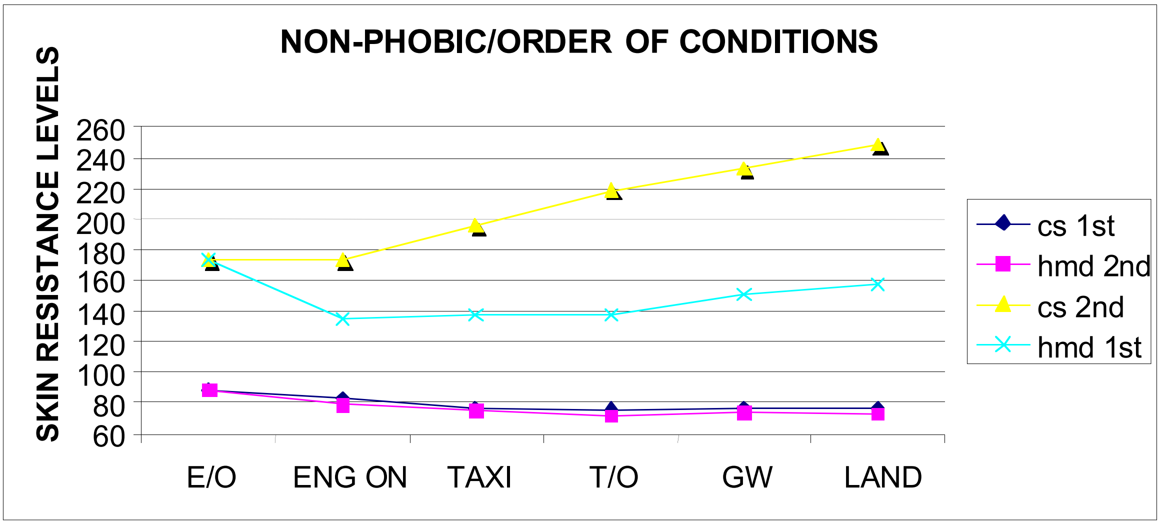

Figure 2. *Skin resistance levels for Computer Screen (CS) and Head-Mounted Display (HMD) conditions according to order of presentation. E/O = eyes open baseline, ENG ON = engines on, Taxi, T/O = takeoff, GW = good weather, LAND = landing*

A 2 x (computer vs. HMD) x 2 (order) x 6 (eyes open baseline and parts of the flight) repeated measures ANOVA was performed. The analysis yielded significant order effect ($F=4.143$, $p < .027$) for skin resistance in the HMD condition and computer screen condition ($F = 106.963$, $p < .0001$) (Figure 2). There was also a significant interaction ($F=3.255$, $p <.035$) for skin resistance in the computer screen vs. helmet conditions, with skin resistance showing more reactance in the HMD condition. Skin resistance changed significantly for different parts of the flight, $F = 5.282$, $p < .005$.

Heart rate showed little variance from baseline throughout either the computer screen condition or the head-mounted display condition. Neither peripheral skin temperature or respiration rate showed significant changes either.

8. Results for Participant with Fear of Flying

In contrast, the physiological response of a participant with a fear of flying in the virtual world appears to be more pronounced. The participant first completed a 5-minute eyes closed, then 5-minute eyes open baseline. The first exposure condition was the computer screen format. When the simulated flight began, skin resistance levels decreased from baseline levels of 249 to 208 (a decrease of 17%) when the airplane engines were turned on. Skin resistance then increased somewhat through the remainder of the flight and was only 9% below baseline (227) at the end of the computer screen flight. The participant was then exposed to the VR world through the HMD next. The physiological response was greater than that experienced with the computer screen format. Even though one might expect a lessening of arousal due to a practice effect, this did not occur. Skin resistance levels decreased by 35% when engines were turned on and decreased another 23% (to 107) at takeoff. The participant could not stabilize physiology during the flight and continued to show high levels of physiological arousal throughout the ten-minute flight. The participant reported subjectively feeling completely present and immersed in the HMD condition and less present and immersed during the computer screen condition. (Figure 1) Heart rate, skin temperature, and respiration rate showed no significant changes due to change in condition.

Table 1. Self-report scores relating to hypnotizability, absorption, stress, and fear of flying

SCORE ON QUESTIONNAIRES	PHOBIC SCORES	NON-PHOBIC AVERAGE SCORES
HIP	9	8
TAS	22	19
FFI	95	20
SSR	55	59
A	14	23
M	15	18
C	26	18
STAI	68	72
State	32	33
Trait	36	43
QAF	172	22

9. Results of Self-Report Questionnaires

As shown in Table 1, the self-report scores for questionnaires relating to fear of flying and attitudes towards flying are dramatically different for the participant with a fear of flying and the participants without a fear of flying. The participant with a fear of flying,however, did not have significantly different scores on either the state or trait anxiety scales, nor on in stress responses as noted by the Self-Survey of Stress Responses. Scores on the TAS and HIP were almost the same for both sets of participants, and both sets of participants subjectively reported being able to become more deeply immersed and feel more present in the HMD condition.

10. Discussion

As has been reported in previous research, immersion appears to be necessary in order to experience presence. [3,33] However, according to earlier researchers it was also felt that presence was a subjective manifestation and not open to objective measurement. [31] This was not found in our study. As predicted, presence was enhanced by more immersive experiences and more immersive experiences (or presence) heightened physiological arousal. Order of presentation of the environments seemed to effect physiological arousal as evidenced by skin resistance levels. (Figure 2) Also as predicted even though the virtual world was a new and novel stimulus for all five participants, the person with a fear of flying experienced much more physiological arousal when exposed to the virtual environment depicting a flight sequence.

Studies have reported that when the phobic's fear structure is activated, autonomic arousal (such as increased sweat gland activity-decreased skin resistance) occurs [20]. Emotional processing theory purports that in order to change a patient's fear structure, the structure must be activated [21]. Real-time physiological monitoring is helping to determine when the patient's fear structure is activated and open to change. Monitoring is also useful as an indicator of when the patient is becoming too aroused and needs to be placed back at a lower level of the fear hierarchy or taken out of the phobic scenario altogether. It may, too, reveal if the patient has become desensitized to a certain aspect of the phobic scenario and should actually be encouraged to move on to the next level of the fear hierarchy. Since this study revealed that more immersive environments yield more physiological arousal, this may serve as a guide for development of treatment systems in the future.

In 1907, Carl Jung discovered that skin resistance (which decreases as sweat gland activity increases) was a means to objectify emotional tones previously thought to be invisible. Skin resistance, unlike EMG and skin temperature, tends to reflect mental events more quickly and with more resolution than other physiological measures [20]. Baseline levels vary widely by individual so percentage change from baseline is normally measured rather than absolute value. It was clear in the results of this study that skin resistance was the single measure that reflected arousal across all participants. Although some participants also showed heart rate increases, it was not a uniform predictor across participants.

Since most virtual environments currently available do include graphics that are somewhat cartoonish, it is useful to note that this has been found in several experiments to be an appropriate level of realism to elicit the fear response in persons with specific phobias [8,13, 22,25]. A study done by Welch et al in 1996 [6] also found that pictorial realism played less of a role in a participant's feeling of presence in a virtual world than did interactivity. This is encouraging and has also been noted in our clinical experience.

Some advantages of VR therapy as compared to In Vivo include confidentiality, safety, control, and flexibility. Since the treatment is done in the therapist's office, there is no loss of confidentiality. Since the treatment is in the office and can be terminated at any moment, it should be "safer" than being trapped on a plane and having severe anxiety or a possible panic attack. Since there is more control of the scenario, with the patient able to at any time remove the HMD or ask the therapist to stop the VR scenario, more patients may be willing to seek treatment. Also, the therapy may be just "unreal" enough that many patients who have resisted therapy due to in vivo approaches are willing to try it. If the patient's main fear centers on airplane landings, one can practice landings over and over in the virtual world. This flexibility allows for more directed treatment and hopefully will require less treatment time, reducing costs [24,25,32].

As compared to Imaginal, the VR system is more highly immersive due to the stimulation of several sensory modalities including audio, visual, and vestibular. Multiple sensory modalities may better prepare patients for an actual airplane trip. Also, since the therapist is seeing exactly what the patient is seeing, and can more easily determine the stimuli eliciting the fear response, therapy can be directed more towards only those parts of the environment causing anxiety [24,25,32].

11. Conclusion

The study revealed some very interesting facts relating to presence, degree of realism, and immersiveness. Although due to having only five participants it lacks generalizability, its findings do appear to warrant a larger scale study of this topic. Previous studies have indicated heart rate changes in response to the feeling of presence in virtual worlds [26]. A larger scale study might increase statistical power to a degree that detection of significant changes in heart rate across conditions would be elucidated. In addition, studies of persons with phobias have found increased heart rate as well as increased sweat gland activity upon exposure to imaginal, video presentation, and in vivo presentation of phobic stimuli [27,29]. In the one participant with a phobia who was studied, only skin resistance reacted significantly to presentation of phobic stimuli. Again, a larger study might reveal heart rate changes in response to phobic stimuli across the group.

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