The Meditation Chamber: A Bio-Interactive Therapeutic Virtual Environment

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ABSTRACT
This paper describes the design and implementation of The Meditation Chamber, a bio-interactive, therapeutic virtual environment exhibited as SIGGRAPH 2001. The project's goal was to design and build an immersive virtual environment that used visual, audio, and tactile cues to create, guide, and maintain a user's guided relaxation and meditation experience. Real-time biometric data was used to partially control the environment, shaping the user's experience. Objective and subjective data collected from the participation of over 400 attendees are presented and discussed.

Keywords
Biometric interfaces, bio-interactive, biofeedback, GSR, virtual reality, meditation, relaxation

INTRODUCTION
Alternative therapeutic techniques related to relaxation and the management of stress are increasingly employed to augment traditional treatment by drug-based, medical therapies. A growing body of results presented in the literature show that these alternative treatments show great promise and warrant continued use and study.

Drug-resistant epilepsy, hypertension, asthma, anxiety disorders, depression, chronic pain, and AIDS/HIV make up only a handful of the medical problems that have been successfully addressed through relaxation/meditation techniques. A 1995 study showed that a group of HIV infected men with sub 400 T-cell counts who were exposed to a collection of relaxation techniques improved significantly when compared to a control group on dependent measures including T-cell count, mood, anxiety and self-esteem [5]. Countless studies support the use of relaxation techniques, particularly Transcendental Meditation, in the treatment of hypertension and other substrates of coronary heart disease [8, 4, 6, 1, 7].

Though not fully known, the root of the effect of these relaxation techniques on physical and psychological health is thought to lie in their ability to stimulate the production of certain important hormones. It has been shown that experienced practitioners of Transcendental Meditation create in themselves the same endorphin release reaction created by physical exertion in experienced runners, often referred to as the "runners high" [2]. It has also been shown that melatonin, thought to be important in health maintenance and prevention of diseases such as breast and prostate cancer, is found at significantly higher levels in regular meditators when compared to non-meditators [3].

One roadblock to the effectiveness of relaxation therapies is the consistency and quality of the experience that the user has. Not all formally trained doctors are knowledgeable enough to administer alternative treatments. Also, many people have difficulty with visual imagery and are not good candidates for meditation exercises. The goal of the research project presented here was to design and build an immersive virtual environment that used visual, audio, and tactile cues to create, guide, and maintain a user's guided relaxation and meditation experience.

There are several possible advantages to using a virtual environment to support meditation and guided relaxation. Patients without good mental imaging skills would still be able to benefit from the use of meditation. Clinicians with minimal training in meditation and guided imagery would be able to provide a consistent, high quality relaxation/meditation experience to their clients. Also, by providing specific meditation environments we can guarantee that participants in future studies of the usefulness of meditation and relaxation techniques all receive identical training and treatment.

The use of meditation and guided imagery is well established as helpful in the treatment and prevention of a number of diseases with high cost in both human suffering and financial terms. The possibility of increasing the effectiveness and repeatability of this type of therapy will receive a great deal of interest from the medical community. This project aimed at creating a working prototype of this system, enabling us to create a compelling demonstration of the potential of this approach.

SYSTEM DESIGN

The system was designed over a period of several months by an interdisciplinary team of computer scientists, psychologists, artists, and educators. The end product was a three phase experience that offered a sampling of basic meditation and relaxation techniques.

Instrumentation

Galvanic skin response, respiration, and blood volume pulse were chosen as the biometrics of interest for this project. These biometrics were collected using the ProComp+, a commercially available device produced by Thought Technologies. The sensors described below are all standard biometric sensors produced by Thought Technologies for use with the device.

Galvanic skin response (GSR), commonly used in lie-detector tests, is a measure of the change in the electrical conductivity of the skin that results from the body's reaction to emotional stimuli. It is fairly useful in measuring an individual's general level of arousal as well as tracking changes in arousal as they relate to events in the individual's environment. GSR is measured by attaching two electrodes to the user's fingertips and measuring conductivity changes in a reference charge passed through the users skin. The reference charge is weak enough that no sensation is created.

Respiration rate was measured using a chest strap that was stretched around the user's upper chest and fitted just below the armpits. The strap was equipped with a length of rubber tubing that flexed and relaxed as the user's chest expanded and contracted during respiration. The change in the length and tension of the rubber tubing was measured and integrated to derive a breathing profile of each user that showed both frequency and amplitude of respiration. As an addition / alternative it is also possible to measure diaphragmatic breathing with an abdominal placement of the respiration sensor.

Heart Rate was measured using a blood volume pulse sensor that monitored cardiac pulse at the tip of the index finger. The data generated was rendered as a line graph showing change in heart rate over time.

The audio-visual content of the environment was delivered to the user via head mounted display. The head mounted display used for this installation was the VFX-3D, produced by Interactive Imaging Systems. This bi-occular HMD does not have a stereo-visual display, but gives the user an approximately 60-degree field of view. The unit’s large, high quality headphones also figured in to its selection for their ability to deliver robust sound and cut down on the intrusion of external noise. A library written by Thought Technologies allowed us real-time access to the stream of data produced by the sensors. We were then able to write code that allowed us to use this data stream to manipulate aspects of the environment. This feedback loop let the user's bio-rhythmic state alter the environment in subtle ways just as the environment worked to relax the user.

Figure One. Image of the sunset taken from initial phase.

Content

This initial phase served to relax the user and introduce them to the experience. After being asked to breathe deeply and relax, the user was presented with a visual depiction of the sun just before sunset. A narrator's voice told the user that the sun would drift lower and lower in the sky as they relaxed, breathed deeply, and flushed their mind of worldly concerns. The sun would then start to move downward very slowly, toward the horizon (see Figure One). As the user began to relax and their GSR declined, the rate at which the sun moved would increase until the sun went beneath the horizon giving way to a peaceful night scene, complete with chirping crickets. If the user was unable to become relaxed or their GSR increased the sunset would slow down. Since we felt it was important to present the user with an early success, after a certain period of constant high or increasing GSR, the system would time out and play through the sunset sequence at full speed to minimize any user frustration. The second part of this relaxation phase operated in the same way as the first, but depicted a moonrise instead of a sunset. As the user relaxed and lowered their GSR the moon would rise higher and higher into the sky. The user’s GSR measure determined the frame-rate at which the sunset / moonrise animation would play. Depending on the frame-rate the user achieved this combined sequence took 2-4 minutes to complete. User’s were not told explicitly of the relationship between their GSR and the frame rate of the animation so that they would make no effort to “play” the environment and would instead concentrate on the experience of relaxation.

The second phase of the experience was a guided, progressive muscle relaxation exercise. The user was coached to flex, hold, and release a set of eight different muscle groups including the legs, arms, abdominals, and shoulders (see Figure Two and Three). Each muscle group sequence was accompanied by gender appropriate visuals depicting the described motion, usually from a first person perspective. Visualization of mouth and eye flexion necessitated the adoption of a third person perspective. Male users viewed a male body performing the exercises while female users viewed a female body. This phase was not interactive, but instead asked the user to listen to the narrator's instructions while mimicking the movement examples visually presented to them on the screen. The progressive muscle relaxation phase lasted roughly 6-7 minutes. The nature of flexing and relaxing the major muscle groups provided a tangible experience of the creation and, more importantly, the release of tension.

The third phase was designed to teach the user a basic meditation called "following your breath". During this meditation the user is asked to focus all their awareness on the sensation of their breath coming and going from their nostrils. If other thoughts enter their awareness during this time, they are told to push them aside calmly and firmly and to remain focused only on their breath. This phase lasted approximately seven minutes and was accompanied by an abstract visual display created by putting several image filters on top of video of a swimming jellyfish. The image seems to pulse in time with the user's respiration. The audio during this segment sounded like calmly rushing water and was sampled from sounds taken from a waterfall. It was the intent of the design, that the user would eventually close their eyes in an effort to more fully focus on their respiratory sensation, shutting of the visual stimulus.

THE INSTALLATION

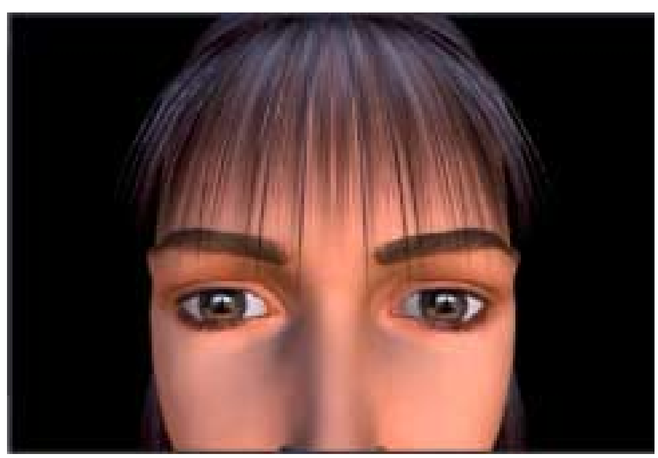
The system was installed at the Emerging Technologies Exhibition at SIGGRAPH 2001. A four-station installation was created to accommodate as many conference attendees as possible while still keeping the installation manageable in terms of cost and staff. We used four head mounted displays, four biofeedback units and four PCs to run the installation. The PCs were networked to allow access a common printer that was used to generate takeaway feedback forms for the participants. Due to high demand and the fact that the experience took roughly twenty minutes from beginning to end, we instituted a reservation system in order to avoid long lines.

When a user arrived at their reservation time, they signed an informed consent sheet and were able to ask any questions they might have about the experience. Each user also completed a brief pre-experience inventory, an instrument that asked them how relaxed they were currently and to what degree they believed they could become relaxed given a calming, fifteen-minute experience. Users were told that their biorhythms would control the environment in subtle ways, but they were not told specifically how this would occur. Again, this design decision was made to minimize the degree to which users would attempt to "play" the environment, attempting to alter their respiration or other biorhythms in order to test the effect they might have on the environment. Having signed the form, users were seated in one of the private booths and fitted with the sensors and the HMD. Once the user signaled that they were ready, the experience was started and the user was left alone in the booth. The experience proceeded as described in the Content section above. The version of the environment exhibited at SIGGRAPH 2001 did not contain an implementation of heart rate and respiration based interaction. However, these data were still collected from each participant. GSR-based interaction was fully implemented as described above.

At the end of the experience, an attendant returned to the booth to help the user remove the sensors and HMD and then escort them to the debriefing area. In the debriefing area, each user completed a post-experience inventory asking how relaxed they felt following the experience, and soliciting any comments they might have about the installation. They also received a feedback sheet and a brief consultation from one of the project's principal researchers.

Figure Two. Male muscle relaxation exercise for arms.

Figure Three. Female muscle relaxation exercise for eyes.



Each user's bio-metrics (GSR and respiration) were printed out as a line graph on the feedback sheet, which contained an explanation of how to analyze the graphical representations of their experience. The consultation included a visual analysis and explanation of the user's data as well as an interpretation of whether or not they had a relaxing experience based solely on what the data suggested. Following the consultation, the feedback form was returned to the user and they were free to leave or remain in the area to discuss their experience further with another member of the research team.

RESULTS

Four hundred and eleven SIGGRAPH 2001 attendees experienced the installation during the five-day exhibition. Analysis of the biometric data generated by each participant is still underway, but we are prepared to report some preliminary observations about the data. Also, we can report on the completed analysis of the subjective measures of relaxation collected in order to assess how effective the installation was in providing each individual with a relaxing experience.

Objective Measures

We have begun to analyze the expansive amount of biometric data collected from the SIGGRAPH attendees, concentrating mostly on the GSR and Respiration data. Preliminary analyses show that two general patterns of GSR profile can account for nearly 75% of the generated data and are each generally accompanied by two distinct respiration profiles. Just over half of the participants exhibit what can be called a novice GSR profile. This means that their GSR level starts relatively high, descends through the first phase of the experience, kicks back up and shows peaks in the muscle relaxation phase, and then begins to decline again in the final phase, ending up at or beneath the low established in the first phase. The top two GSR graphs shown in Figure Four are typical of this profile. Breathing patterns in individuals exhibiting the novice profile tend to be steadier and deeper in the final phase than in the first phase. The second profile, which accounts for nearly a quarter of the GSR data, is termed the expert profile. Individuals exhibiting this profile show precipitous drops in GSR during the first phase, entering a very low and often flat GSR state before the muscle relaxation phase begins. This flat-line state is typically maintained throughout the remaining two phases of the experience, and is accompanied by a very steady but not necessarily deep breathing pattern. Individuals exhibiting the expert GSR profile also show very consistent respiration rate and amplitude throughout the experience. The GSR graph at the bottom of Figure Four is typical of the expert profile. As we move forward, we plan to employ Principal Component Analysis to verify these preliminary findings.

Subjective Measures

The first question on the pre-session inventory asked the user to rate their current level of relaxation from 1 (very

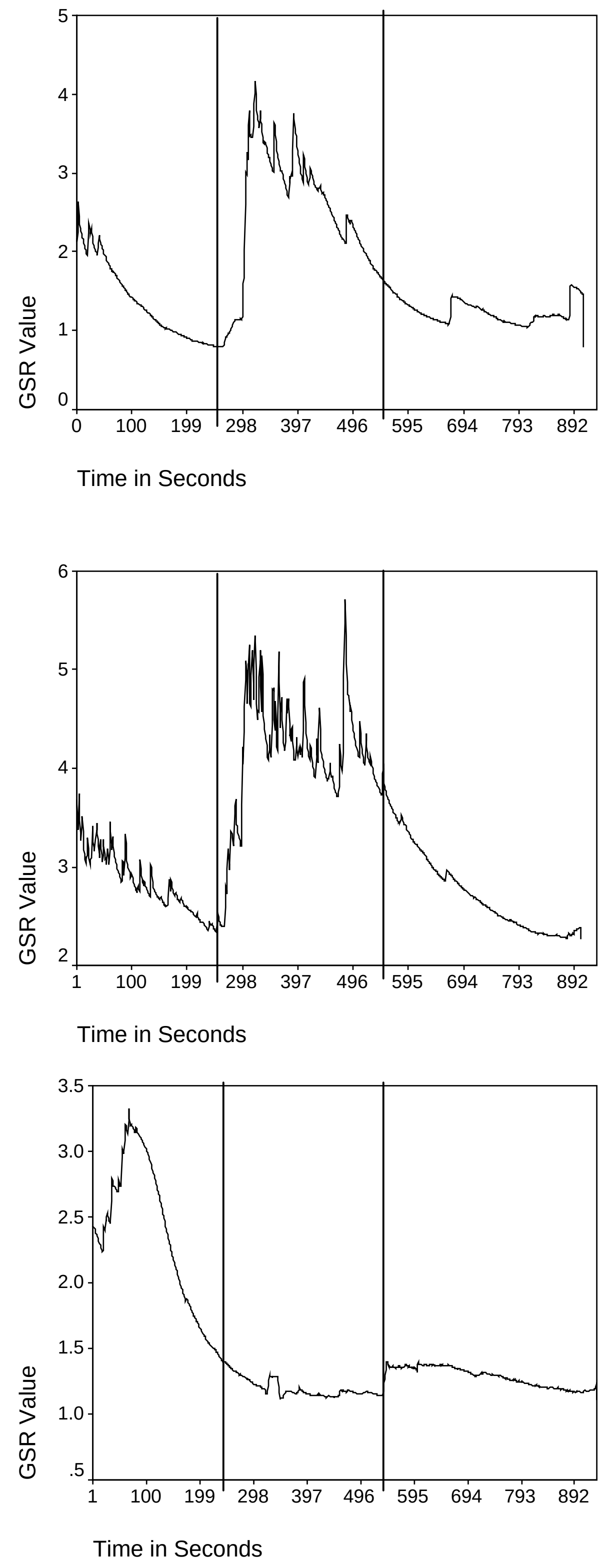


Figure Four. Sample GSR graphs typical of the novice (top two) and expert (bottom) profiles. Lines are shown to estimate the transition points from one phase to the next.

anxious) to 10 (very relaxed). The second item was a YES/NO question asking whether or not the user felt that

they would be able to become relaxed given a calming fifteen-minute experience. The post session inventory also contained two items. The first asked the user to re-assess their level of relaxation using the same 1-10 scale, with 10 being very relaxed. Following this was a free response item that asked the user for any comments, criticisms of, or insights about the experience.

A t-test showed that post-session relaxation ratings ($\underline{M}$=8.00, SD=1.69) were significantly higher than pre-session ratings ($\underline{M}$=5.63, SD=1.75), $\underline{t}(410)= -24.45$, $p=.0001$. Forty-nine of the 411 participants reported equal or lower levels of relaxation following the experience, with 18 of these reporting the same level, and 30 reporting decreases in relaxation of 1-3 scale points. The other 362 participants reported levels of relaxation 1-8 points higher following the experience, with a mean difference of 2.88 scale points between pre and post session ratings. There were no gender differences on either relaxation rating.

Twenty participants reported that they did not believe that they could become relaxed by the experience. Of these, 2 reported equal and 2 reported lower relaxation ratings following the experience. The rest reported higher levels of relaxation. As this suggests, there was no significant relationship between response to item two of the pre-session inventory and the difference between pre and post session relaxation ratings, $r(411)=0.023$, $p=.642$. There was also no relationship between the time of day that the session occurred and either relaxation rating.

DISCUSSION AND FUTURE WORK

We decided to refer to the novice profile as such because people who reported little or no experience with meditation or other relaxation techniques displayed it most often. Similarly, the expert profile gets its name from its association with individuals who reported high levels of experience with relaxation techniques, meditation, yoga, and even distance running. The novice profile is characterized by relatively mild GSR drop in the first phase and an extreme GSR reaction during the muscle flexing activities of the second phase. In contrast, expert profilers show little if any GSR reaction during the muscle relaxation phase, maintaining a nearly flat level throughout the latter two phases, following an initial, precipitous drop. In terms of respiration, novice profilers are more influenced by the coaching they receive in the third phase of the experience, causing them to show a deeper, slower breathing pattern in this phase compared with the first. Expert profilers seem to have a very consistent breathing pattern with which they are comfortable, as it is maintained without much change in frequency or amplitude throughout the experience. Breathing patterns for all participants are somewhat similar in the second phase due to the frequent held breaths associated with various muscle flexions.

The subjective data clearly suggests that most people experiencing the environment emerged significantly more relaxed than they were when they went in. Of course it can be pessimistically argued that this effect might be due to the fact that participants were able to sit quietly for fifteen minutes. Though we discount the strength of this argument, a baseline condition in which participants are seated and monitored for the same length of time without exposure to the environment's audio or visuals is planned to address it.

There are also plans to fully implement the heart rate and respiration based interactivity originally designed to be included in the system. Heart rate will be used to control the audio in the environment's final phase, while respiration will be used to control the pulsation of the visuals. Meditations in addition to "following your breath" will also be included in later versions of the system.

A beta version of The Meditation Chamber has been distributed to 20 clinical partners across the US for evaluation and feedback. With respect to the more general topic of bio-interactivity, members of the research team have begun several explorations of the use of GSR and other biometrics in interactive art, kinetic typography, and augmentation of the sensing abilities of remote intelligent agents.

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