ABSTRACT

Our project used a virtual environment called DarkCon to simulate a military reconnaissance mission. In this study, we investigated the differential effects of priming on a group of 64 civilians. Half were given a military-style, and half a game-style instructional video and briefing. We tested subjects for simulator-sickness, immersive tendencies, self-reported degree of presence, and recall of scenario elements. Psychophysiological data (skin-conductance response and heart rate) was also recorded for each subject. We hypothesized that the priming condition would result in different behavior within the virtual environment, differences in physiological response, and possibly differences within subjects' recall of their experience. Implications of our findings and directions for future research are discussed.

CR Categories J4.1 Computer Applications Psychology I.6.6 Simulation Output Analysis
Additional Keywords: Virtual Reality, Training and Simulation, Behavioral experiments, presence

1 INTRODUCTION

Our research lab was established by the United States Army as a university research center tasked with investigating ways to make training for soldiers more effective. We set out to show that more affective immersive training environments could contribute to more effective training systems for soldiers. Our project focused on immersive training environments delivered via traditional virtual reality techniques. We started with several related hypotheses: a) That virtual environments for training can be made more emotionally evocative, b) that emotional response in virtual environments tends to increase users’ overall physiological arousal states, significantly impacts users’ behavior, may improve immediate recollection of scenario experience, and may enhance retention of scenario experience, and c) that inclusion of additional sensory modalities in the scenario experience will heighten the responses listed above.

Given the increasing trend towards using games for military training, we also set out to demonstrate that encouraging a specific mental schema in a user that is appropriate to the scenario, as either a game or a serious training mission, induces a particular cognitive approach that affects the user’s emotional response.

We first developed methodologies for creating a more emotionally evocative virtual scenario for use in our experiments, resulting in the scenario DarkCon. DarkCon is an immersive virtual environment, run on a custom Performer GL engine on the SGI Reality Engine, and experienced through a head mounted display (HMD) providing the user with a fully explorable 3D environment. The participant navigates through this virtual space via a hand-held joystick and an InterSense tracking system attached to the user that provides 6 degrees of freedom (DOF) information back to the simulation.

DarkCon was based on the premise that the integration of sensory modalities mitigated the need for photo realistic graphics. We call this approach “cognitive realism”. We used techniques from art, design, theater, film, story, and psychology in the design process, as well as the latest information from cognitive and neuro-sciences on how our brains respond to and integrate sensory stimuli for emotional response.

The DarkCon experience is, to our knowledge, entirely novel; therefore, we ran into many novel obstacles. Certain functionalities were not available and had to be built by the team from scratch (for details, see [5]). Software tools also had to be created. This work resulted in a system that could be used, and our subject experiments started in earnest in Spring 2004. This experiment and its initial results will be the focus of this paper.

2 CIVILIAN EXPERIMENTS ON PRIMING

One factor we suspected as a strong influence on the responses of an individual in a training scenario is the set of expectations he or she has going into the virtual environment (VE). Given the ubiquity of gaming in the generation most appropriate to join the Army we asked ourselves the question: Would there be a difference in behavior if the subject believed the VE scenario was a game, as opposed to a serious exercise?

We therefore chose to investigate the effects of priming on behavior in DarkCon. Priming can inform individuals what to expect, but it can also influence the way in which they perceive subsequent events. Priming can be induced by both visual and language stimuli and creates a bias for the participant, whether they are aware of it or not. We expected that the priming given to the subjects in our tests would influence their later perception of the virtual environment as either a competitive (game) or a responsible (military) situation. Our hypothesis was that subjects would behave less responsibly if they believed it was “just a game” with its corresponding impunity to serious consequences. For military priming, we expected subjects to be more observant and careful.

We tested 63 civilian subjects, informing half of the subjects they were about to experience a video game, and the other half that this was a serious training mission. The wealth of data that resulted from this instrumented free–will (i.e. not laboratory controlled) experiment was overwhelming. We found that none of the physiological data emerged in a usable state and required a great deal of clean up. Techniques had to be evolved to facilitate this tedious chore and took more time than anticipated. In addition we realized we needed sophisticated visualization tools to make sense of the data beyond the spreadsheet and statistical analysis. To this end we created a tool called Phloem that enabled playback of each user experience with an overlay of the physiological data. It also serves as a database of each experience and can be queried for aspects of the experience, such as whether a particular item was in the user’s field of view, or how actively the user observed the environment (as measured by aggregate head movements).

Our data required a complex multi-variate analysis process that was jointly developed by our team and our contract analysts.

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3 METHODS

Subjects were randomly assigned to a priming condition in advance of their arrival at the testing facility: game-style priming (n=33) or mission-style priming (n=30). Posters reflecting videogames and military missions were displayed in the briefing room for each subject group, respectively. After giving informed consent, participants filled out a slightly modified Immersive Tendencies Questionnaire (ITQ) [1], and the Simulator Sickness Questionnaire (SSQ) [2-3]. They were then brought into our lab’s Virtual Reality theater, where the simulation was displayed using a custom spatialized (i.e. 3D) sound system consisting of a 10.2 speaker set-up (10 speakers and 2 sub-woofers) including a “rumble floor” with ten low frequency transducers to provide passive haptics effects, and an SGI Reality Onyx computer to compute and display the scenario.

Participants were fitted with electrodes for physiological measurement of heartrate and skin conductance, collected using the Cleveland Medical BioRadio 110 wireless acquisition system. A skin conductance sensor was built to be used with the BioRadio 110, which has preset gain of 1 and 10 mV/µS. Both EKG and SCR channels were recorded with 16bits resolution and a sampling rate of 640Hz. They were then fitted with an InterSense Technologies model IS900 6DOF tracking system with navigation wand and Kaiser Electro-Opticals ProView XL-50 head-mounted display (HMD). Preliminary training was necessary to help the subjects familiarize themselves with the specific skills required within the 3D environment; therefore, a simple orientation environment was constructed to train the subject for his or her required tasks. Physiological data was recorded during this training orientation to provide baseline metrics (for details on baseline acquisition, see [5]).

Before the participant was presented with the DarkCon scenario, he or she was given a mission briefing (via video) that had been designed with the priming condition in mind. Participants in the military-primed group were given their instructions by a person introducing himself as a military officer and addressing them as “soldier”, whereas the game-priming group was briefed by a civilian who told them about the fun role-playing game they were about to experience. While the instructional videos had different contexts, the actual instructions given were identical between priming groups.

The scenario environment represented a small area of an unnamed Eastern European country. Participants were instructed to walk through a culvert and up to a designated building, while determining a. whether the inhabitants of the area were refugees or paramilitary rebels, and b. which (if either) group was travelling through the culvert. Objects in the culvert served as corroborative detail or, intentionally placed clues designed to make participants draw conclusions about the culvert inhabitants (see figure 1). If the area appeared hostile and rebel-controlled, participants were to place a GPS transmitter on the building in order to guide a missile strike, and leave. Participants were instructed to be cautious, and observant, and were told that they would report their findings.

4 DATA ANALYSIS AND RESULTS

The experience was divided into time epochs: inside the culvert, outside the culvert, and end-of-scenario (an animated sequence in which the subject is ‘seen’ by guards, steps on a landmine, or is shot). Data was collected individually for each epoch, as well as combined to represent the total experience. Preliminary analysis of correlations between other variables related to behavior revealed some obvious, but significant relationships. The heading (subject's aggregate lateral HMD movement) and pitch (subject's aggregate vertical HMD movement) were correlated with aggression and fear, respectively, in the game-primed condition.

Figure 1: Scene from inside the culvert.

The DarkCon simulation then began, with fully-spatialised audio and 3-D visual input to the participant. During the scenario, physiological data was continually recorded. The DarkCon environment server was synchronized with the computer controlling the physiological recording device in order to correlate the psycho-physiological reaction of the participant with events and situations in the scenario. When an end of scenario (EOS) condition was met (being caught by a guard, for instance), the VR equipment was removed from the participant who was then seated and given a structured interview about their experience. Interviews were recorded and coded for later analysis. Finally, they were taken to another room and provided with a second set of follow-up questionnaires designed to evaluate “presence”: a modified version of Witmer and Singer’s Presence Questionnaire (PQ) [1] and of Usoh and Slater’s Virtual Environment Questionnaire (VE) [4]. They also completed the SSQ once more [2-3]. One week later, the same structured interview was carried out by phone, in order to assess memory retention of the participants.

Figure 2: The Phloem tool used for data analysis.
outlying values. Therefore, data points outside the upper and lower limits of each variable were removed. Differences between priming groups were computed on the subsequent limited set using one-way ANOVA. A significant effect was found on total time spent in the scenario environment: the military-primed group stayed in the environment longer (F=6.015, p=0.018). The military-primed group also demonstrated greater immediate recall overall (from structured interview) than the game-primed group (F=4.867, p=0.032). Memory durability scores were calculated as the difference between immediate after-action recall and delayed recall, from telephone interview one week later. The military-primed group demonstrated poorer memory durability on items located outside the culvert (F=5.610, p=0.022). Finally, the game-primed group showed greater variance in SCR during the end-of-scenario animation (F=6.092, p=0.017). This variable violated the equal-variances assumption of ANOVA, however; therefore, a Brown-Forsythe robust statistic was calculated, confirming the significance of the result (p=0.025).

5 DISCUSSION

Further discussion relies on the use of heading and pitch together as a reliable index of observing or exploratory behavior. Preliminary analysis seems to indicate that this is the case. Firstly, heading and pitch are modestly correlated with one another throughout the environment experience. This may suggest that they vary, together, from a baseline determined by individual predisposition. Secondly, pitch (which, being vertically oriented, is not affected by navigation) is correlated with time spent within the culvert, indicating subjects’ taking time to observe their surroundings. However, pitch for the entire experience was negatively correlated with time spent outside the culvert.

As shown above, exploratory behavior (as measured by heading and pitch together) results in greater immediate recall. Total immediate recall is correlated with heading and pitch within the culvert and heading and pitch for the total experience, as well as pitch outside the culvert. In addition, the impact of heading and pitch together on delayed recall approaches significance within the culvert, and pitch alone approaches a significant impact on delayed recall both outside the culvert and in total.

It also appears to be the case that, in order to commit what one has observed to memory, a change in physiology must take place. This is demonstrated by the examination of delayed recall, both outside the culvert and in total, which was significantly correlated with many different dimensions of heartrate. In addition, pitch throughout the experience was correlated with variance in skin conductance response (SCR) within the culvert. Research has demonstrated that emotional involvement affects memory processing (citations), and that involvement may be measured by SCR (citations); our results support these widely held conclusions.

It is also interesting to note subjects’ self-evaluation of the frequency with which they play various computer games, and its interaction with physiology. It appears that gameplay experience generally limits the increase in heartrate that we would expect to see in an emotionally valent scenario. One might think that this was due to boredom, through general experience of similar sorts of games and tasks; however, game play was also associated with higher scores on the ITQ (unsurprising, a matter of self-selection) and PQ (in the specific category of first-person shooters). No negative correlations were found between gameplay experience and heartrate during free-walking baseline. This appears to indicate that the greater a subject’s gameplay experience, the higher threshold of stimulation is required for emotional involvement measured physiologically. Further investigation is required into the facets of individual differences that must be taken into account when designing virtual environments for training purposes.
The manipulation of priming conditions appears to have made an impact on subjects' behaviour within the DarkCon scenario, though to a lesser extent than expected. The fact that military-primed subjects spent more time in the scenario than game-primed subjects is potentially significant in many ways. Firstly, it speaks to a greater degree of caution and deliberation employed during exploration of the environment. Since there were no significant differences between groups within individual epochs, it appears that this reflects an overall trend, and not an increase in any particular behaviour (for instance, exploring the culvert for objects). This supports our hypothesis that differences in behaviour would be observed, and does so in a direction that is unsurprising. The military-style priming made the scenario task a serious exercise, in which participants were to be evaluated based on task performance ("a lot of people are counting on you, soldier"). Subjects in the game-style priming group were presented with a fun game, without the likelihood of consequences for their actions. As a result, it seems, the former group exhibited more caution, as reflected by the amount of time they spent in the environment overall.

This idea, that military-primed subjects behaved more carefully within the scenario, is also supported by their greater recall of objects, people, and vehicles immediately after the experience. This figure may be interpreted in one of two ways: either a) military-primed subjects actually observed more of the items in the scenario, or b) both groups of subjects saw the same number of items, but the military-primed group paid more attention and/or committed more items to memory for later report. Immediate recall was found to be correlated with "exploratory behaviour", described above as head movement related to looking, suggesting that they observed more objects; however, there were no significant differences found between the amounts of "exploratory behaviour" exhibited by each group, suggesting that the military-primed group saw the same number and reported more. In either case, it appears likely that the military-primed subjects were behaving seriously within the scenario and treating it as a genuine mission, more so than their game-primed counterparts, as reflected by their performance. At this time, there is no data to confirm which objects in fact passed within each subject's field of view. This fact, in combination with the "structured interview" method of debriefing, results in a measurement not of what subjects actually remember, but of what they are likely to verbally report. Likelihood of report and recall are not unrelated, however, and so we feel that our data remain reliable for this type of comparison.

The military-primed group also exhibited lower memory durability scores, for items observed outside the culvert. This does not mean that military-primed subjects remembered fewer items than game-primed subjects - analysis shows no difference between the mean amount of items recalled after the one-week delay. These subjects forgot more in the interim between after-action and delayed recall, it would appear, simply because they had more to forget. This may have implications for the training applications of virtual environments - the method and mindset within which one approaches a task may allow greater performance in the short term, but may have lesser impact on lasting memory. However, it is also the case that simply recalling observations is a different type of learning than would be required to improve performance on the task itself (in psychological terms: recall of observations would utilise the combination of semantic and episodic knowledge, while repeating the task would utilise semantic and procedural). Finally, the sole difference in physiological arousal between groups was in the variance of skin conductance observed during the end-of-scenario epoch. Military-primed subjects showed less variance in SCR during the end-of-scenario animation than game-primed subjects. Variance is a representation solely of deviation from baseline levels; that is, it represents the largest difference between maximum and minimum levels of SCR reached in a particular time period, and is an indication of the magnitude of physiological arousal. Therefore, it appears that the military-primed group was less startled or fazed by the end-of-scenario sequence than the game-primed group. This was not due to a lesser degree of presence (as measured by either the Presence or Virtual Environments Questionnaires), nor to a different understanding of the goals to be accomplished in the environment (no significant differences between groups on their recall of goals). Such a finding seems to indicate that the military-primed group might have been less emotionally involved in the virtual environment; in this case, we would expect to see differences in SCR and heart rate between groups throughout the experience, which do not occur. This is somewhat surprising. It is possible that the game-primed group was unprepared for the difficulty of the task, and was thus more surprised at being ‘caught’ than the military-primed group, who may have expected such an outcome.

6 Conclusion and Continuing Work

Overall, the priming manipulation resulted in a lesser effect than that which was expected. This may be due to several factors. One possibility is that individuals’ prior experience with video games had an effect on their behaviour within a virtual environment that we did not foresee. To this end, we grouped individuals for analysis by their gameplay habits (measured by the ITQ), rather than their priming condition. Some initially promising differences were found, such as a significant effect of first-person shooter game habits on total time spent within the scenario. However, such findings must be interpreted extremely cautiously: since we did not anticipate an examination of the effects of gameplay, we did not evenly distribute subjects in groups, nor did we ensure a sufficiently large and varied sample. Group sizes were thus extremely uneven, making such analysis suspect, and rendering impossible any examination of the interaction between gameplay habits and priming condition. We suspect that such an interaction exists, and propose that future experiments examine the impact of individual differences such as videogame experience on behaviour in a virtual environment.

We also considered the possibility that among a civilian population, military behaviour might be only minimally different from non-military behaviour, due simply to lack of experience. To this end, in 2004 we developed a portable version of its simulation system that runs on a commodity cluster of 3 PCs and provides the full immersive VR setup (Kaiser HMD and 6 DOF Tracking via the Polhemus magnetic tracker, with 5.1 sound). This system permitted our project to bring the experimental setup to Army bases for testing on a soldier subject population to provide results more directly applicable to soldier training systems. This was done in May 2005, and data from that study is now being processed. In addition to these analyses, we have begun recruiting for focused studies on olfaction and infrasound. Thereafter we will deliver an experiment design for the use of aversive stimuli in virtual training environments.

It is clear from the results of this experiment that further study of the training applications of virtual environments is required. It may be especially valuable to investigate the effects of individual differences, such as videogame experience and habits, on the effectiveness of such environments, and subjects’ behaviour within them. We invite others to scrutinize these factors more closely.
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REFERENCES


