The Importance of Significant Information in Presence and Stress
Within a Virtual Reality Experience

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Abstract: We conducted a pilot study on the relationship between significant information, presence, and stress. The experiment was performed with a medical emergency training simulator based on virtual reality, and was conducted with two sets of subjects: critical care specialists and people other academic degrees in scientific fields who lacked experience in medicine. Those lacking experience were trained to properly act with the concrete clinical problem being simulated. During the experiment, the Galvanic Skin Response (GSR) of the subjects was recorded, and presence and stress questionnaires were completed by the subjects. The specialists in critical care with first hand experience report a high degree of presence in both environments tested, but subjects without such experience have a high degree of presence only in the stressful environment. This study found that results from stress and presence measurements show an evident correlation, making apparent a close relationship between both variables. Our results also show the importance of significant information when a high degree of presence or stress is needed in a VR training simulator.

INTRODUCTION

Intensive care specialists are needed to work in critical situations under high levels of stress. This kind of strain has a great effect on the emotional state of the medical specialist, and so they have to be prepared to work in such adverse conditions. Hence, training simulators in this field must not only provide an environment to teach cognitive skills necessary for patient assessment, they also need to elicit that emotional state in the trainee. In order to achieve those capabilities, training simulators can use virtual reality (VR) technology, which may induce more intense feelings in the trainee.

In this context, presence, as a subjective sense, has been argued to be a very important factor for human performance in general VR systems. Furthermore, studies on this subject have found a relationship between the level of presence and stress. If the recreated virtual environment presents a stressful situation, a high degree of presence will yield a high level of stress. So, in this kind of environment, stress measurements could be used as indirect presence indicators. But we can go further by hypothesizing that eliciting stress in the subjects exposed to a virtual experience will help to achieve higher degrees of presence. This last hypothesis is discussed in this paper.

In this work we also study how significant information presented in the virtual world concerns the elicited stress and presence. The same stimuli can provoke very different reactions depending on the significance of the presented information. For a medical specialist with real experience in critical care, a virtual patient evokes feelings and memories that can increase both stress and presence. However, subjects without that real experience tend to respond differently, even with the same environment and stimuli.

METHOD AND TOOLS

Training Simulator Description

The experiment discussed in this work was performed with UVIMO, a medical emergency training simulator based on VR and developed for this research. UVIMO provides a virtual environment consisting of a stressful emergency situation with realistic 3D graphics, including a virtual patient lying down on the floor, medical equipment placed around him, and the complete recreation of a typical environment in which the action occurs.
Sense8 WorldToolKit has been used as the simulation engine. A Virtual Research V8 Head-Mounted Display (HMD) was used as the visualization device, and an Ascension Technologies Flock of Birds was used to track head movements.

The virtual patient was presenting an acute myocardial infarction, with a clinical history of ischemic cardiac myopathy and diabetes. He was modeled by means of an expert system, which contained the rules that allowed the patient to respond to the treatment and to progress by himself. The subjects were asked to treat him within UVIMO in two different scenarios: a quiet living room, and a noisy street. Figures 1 and 2 show a snapshot of these two virtual places. The goal of this choice was to provide a non-stressful environment and a stressful one independent of the action to be carried out within them.

Interaction was managed by an assistant who played the role of a nurse, receiving orders from the subject under test. The subject could ask the assistant for any information not directly available in the virtual world, like arterial pressure, temperature, etc. In addition, the assistant could apply any treatment the subject asks for.

**Participants**

The experiments were done with a total of twelve participants who volunteered for this study, ranging in age between 26 and 47, made up of 5 males and 7 females. There were two sets of subjects: critical care specialists (aged between 31 and 47; 3 males, 3 females), and people with similar academic degrees in other fields of science, and without experience in medicine (aged between 26 and 33; 2 males, 4 females).

The former group, called Group A from now on, reported less experience in using computer than the latter one, called Group B from now on.

Group B was trained in a one hour tutorial that discussed how to treat this specific clinical problem, including the use of available drugs and medical equipment, as well as their effects in the case of inappropriate application.

**Measurements**

Two main types of measurements were taken: questionnaires to estimate the level of stress and the degree of achieved presence, and physiological measurements of Galvanic Skin Response (GSR). In addition, significant postural movements and attitude changes were noted.

**Questionnaires**

A presence questionnaire by Slater, translated into Spanish, was used to estimate the degree of presence achieved in the virtual experience. The original questionnaire consisted of five questions, the answers to which were rated from 1 to 7. A sixth question concerning the virtual patient was added. The Presence Index (PI) was taken as the number of questions
rated as 6 or 7, normalized, and expressed as a percentage.

In order to estimate the induced stress, the Stress Arousal Checklist (SACL)\(^7\) was used. The SACL is a state measurement of stress and arousal. In other words, the SACL can measure how stressed or aroused an individual is at any particular time. It does not measure a person’s tendency to be stressed or aroused. This test gives a number from 0 to 18 as stress index. A normalized index, expressed in percentage, is used in this paper:

\[
PI = \frac{1}{6} \sum_{i=1}^{6} Q_i \times 100; \\
\text{if rate(i-th question) } > 5 \\
0 \quad \text{otherwise}
\]

\[
SI = \frac{\text{SACL stress index}}{18} \times 100
\]

**Physiology**

Galvanic Skin Response (GSR) of the subjects was recorded by a skin conductance module Coulbourn V71-23, using DC coupling, a sensitivity of 100 mV/µS and two 8mm AgCl/Ag disposable electrodes placed on the middle and index fingertips of the left hand (all the subjects were right-handed). The analog signal was acquired by a National Instruments NI-6036E acquisition card and a software tool developed for this experiment.

**Behavioral Annotations**

In addition to the above measurements, all significant postural movements, such as pointing or trying to touch virtual objects, were noted. The subjects’ attitude to the assistant was also annotated. The idea behind this is that involuntary movements or attitude changes may be signs of high presence.

**The Experiment**

Before starting each session, the subjects were informed about the methodology of the experiment, and the measurements to be taken. Each session lasted for about 60 minutes, consisted of three different trials, and was carried out with the following scheduling:

1. Estimation of stress previous to the experience
2. Control trial (first trial)
3. Estimation of stress in the control trial
4. Virtual experience in the quiet environment (second trial)
5. Estimation of stress and presence in the second trial
6. Virtual experience in the noisy environment (third trial)
7. Estimation of stress and presence in the third trial

GSR was measured during the three trials, including a period of 90 seconds before the beginning of each trial to obtain the baseline. During this time, the subject was asked to be as relaxed as possible.

**Control Trial**

For the first trial, a task was chosen which did not require specific knowledge or capabilities related to medicine. Subjects were asked to play the popular game 'Simon,' in which they had to reproduce an increasing random sequence of colours and sounds. This trial lasted four minutes. When the subject failed the sequence, they had to start from the beginning again.

**Virtual Experience in the Quiet Environment**

In the second trial, subjects were exposed to UVIMO in a quiet living room (see Figure 1). However, it was not a completely silent environment. Beeps from medical equipment could be heard, as well as verbal communication between subject and assistant. This trial had a duration of three minutes, independent of the state of the virtual patient.

**Virtual Experience in the Noisy Environment**

The third trial took place in a noisy street. Subjects were exposed again to UVIMO in that environment (see Figure 2). This trial had a duration of three minutes, independent of the state of the virtual patient. In this case, the noise acted as a stressful element, and made communication between the subject and the assistant more difficult.
RESULTS

Questionnaires

The SACL, used to provide a stress index (SI), was administered four times to each subject: once before the beginning of the session (SI\(_0\)), as a baseline measurement, and once immediately after each trial. The increment of i-th trial stress index (SI\(_i\)) relative to SI\(_0\) is defined as:

\[
\Delta SI_i = SI_i - SI_0
\]

Figure 3 shows \(\Delta SI\), for both groups of subjects. It is easily seen that all trials produce a positive increment of stress. The control trial increases the SI in a small amount, 10% for specialists and 4% for non-specialists. It is important to take into account that subjects from Group A reported significantly less use of computers in their work than subjects from Group B, which could explain this difference.

Similarly, the stressful virtual environment elicits a high increase of SI, approximately 30% in Group A and 20% in Group B. The obvious difference between the two groups is in the second trial, where subjects were exposed to UVIMO within a quiet virtual environment. Subjects without real experience in critical care do not show much more increment of SI than in the control trial. However, subjects with that experience present increments of SI that are similar to those in the third trial.

These results suggest that for Group B, the content of virtual experience has not contributed to increasing SI. However the noise presented in the third trial acted as a stressful element, which may justify the high \(\Delta SI_3\). However, for Group A, the content seems to be the main stressor, as the clinical problem was the same in the second and third trials. For Group A, the differing trial is clearly the first one, because \(\Delta SI_1\) is much lower than \(\Delta SI_2\) and \(\Delta SI_3\).

Figure 4 shows the obtained presence index (PI) for both virtual experiences and groups. It is clear that Group A presents similar PI in both experiences, while Group B reports very different PI in both trials. The first trial elicited a very low level of presence in Group B, while the second trial provokes a similar level of presence in both groups.

The correlation between our measurements of stress and presence is evident. High stress levels and high presence indicators are clearly
associated. On the other hand, a low degree of presence is also associated with a low stress measure.

**Galvanic Skin Response**

GSR was recorded for all subjects to obtain an objective estimator of stress. A baseline period of 90 seconds was recorded before starting each trial. The average value of GSR over this period has been taken as GSR baseline, and this value is used to express GSR in a relative way, skipping the great inter-individual variability of raw GSR. So, we use GSR* defined as Galvanic Skin Response.

\[
\Delta \text{GSR} = \frac{(\text{GSR} - \text{GSR Baseline})}{\text{GSR Baseline}}
\]

Figure 5 shows the tonic level of \( \Delta \text{GSR} \) averaged for each group of subjects, every ten seconds. In continuous lines, the three trials for Group A are represented, and in dashed lines, the three trials for Group B.

The first remarkable finding is the sheer rise after the first ninety seconds, just at the beginning of each trial. This rise is clear in the three trials and the two groups of subjects, but in Group A it is noticeably larger. It is obvious that GSR, as an arousal indicator, increases when each trial begins. The differences between Groups A and B can not be explained by the special significance that the simulated situation has for Group A subjects, because that difference also appears in the control trial, which has no relation with medical activities. As commented previously, Group A reported less experience with computers than Group B. This could be the reason for this higher GSR during the trials.

In Group B, a slight decrease of GSR tonic level can be seen in Trials 2 and 3, while not in the control trial. On the other hand, Group A presents the opposite effect. But the high variability of these signals undermines this phenomenon in itself. Larger groups are necessary in order to confirm or discard this effect.

Anyway, it is clear that average tonic levels of GSR are not good estimators of stress or presence. In this case, the tonic level of GSR can only be used as a generic arousal index. Although it can sometimes be confused with an erroneous stress or presence index, control trials confirm that this is not the case.

**Postural Movements**

During Trials 2 and 3 all significant movements of subjects were annotated. Although it is diffi-
cult to quantify this kind of behavior, it was clear that Group A subjects made more significant movements than Group B while in the simulator. They include pointing to virtual objects, head movements, and a sharper attitude with the assistant when the virtual patient state was more complicated.

Group B subjects, however, were much more static during the experience, especially during the second trial. This leads to suggest that presence was greater for Group A than for Group B.

DISCUSSION

Subjects from Group A, specialists in critical care with first hand experience similar to this virtual experience, report a high degree of presence in both environments. However, subjects from Group B, without such experience, have a high degree of presence only in the stressful environment. Hence, the information available in the virtual world has a different meaning for the former than for the latter, even when all of them have enough knowledge to act within the virtual world in a proper way.

We hypothesize that relationships between the virtual world and experience in the real world could play a very important role in eliciting some emotional engagement, which leads to increased presence.

In addition, a strong correlation has been found between increment of stress and presence. It seems to be clear that both variables are closely related. In fact, it has been argued that presence could be a stress generator if the virtual environment is stressful, which is a very reasonable assumption. However, Group B presents very different degrees of presence in both quiet and noisy environments, and there is no good reason for this phenomenon if we only take into account the differences between the two environments. It can be argued that traffic noise makes the second environment more realistic, as it presents multimodal stimuli, but the first one also has visual and auditory stimuli, and the interaction with the assistant is based on a conversational interchange. In addition, sound is coherent with the virtual world in both cases.
On the other hand, it can also be argued that noise and consequent difficulty in communicating with the assistant is a clear stressor, and so, the increment of stress in Group B within the noisy environment could be explained by the noise itself. Then, the increment of presence in this last case could be caused by the stress, and not vice versa.

Postural movements seem to be an interesting indicator of presence, as pointed out by other authors.\textsuperscript{9,10} Trials in which a high index of presence was measured correspond to those in which subjects made more involuntary movements. However, it is necessary to define a procedure to quantify this behavior in order to obtain a reliable index of presence.

Regarding objective measurements based on psychophysiological signals, the use of averaged GSR to assess the emotional state can be found in the literature.\textsuperscript{10,11} In this paper, the relationship between averaged GSR, stress, and presence has been explored. It has been shown that averaged GSR can not be used as a stress or presence index. Here, it seems that GSR is just a generic arousal index. The relationship between this arousal and stress or presence is not clear. This has been proven by means of a control trial.

CONCLUSIONS AND FUTURE WORK

In this paper, a pilot study on the relationship between significant information, presence, and stress has been presented. Our results suggest the importance of significant information when a high degree of presence or stress is needed in a VR training simulator.

Our results suggest a strong and close relationship between increments of stress and presence, because each one could be cause and consequence of the other. This is an interesting finding because we can include some stressors in VR simulators in order to improve their presence elicitation. However this must be the objective of further research because, as suggested in Mosbruger,\textsuperscript{12} some kinds of stress can provoke frustration and decrease the sense of presence.

Experience in the use of computers could be an important variable that has not been strongly controlled in this experiment. Further research should treat this issue very carefully. In addition, stress sources must be better isolated in order to ensure their apparent role in the measured presence. Moreover, larger groups should be considered. The work presented here is just a pilot experiment, and all these results should be considered cautiously.

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