VRSART A Tool For Evaluation of Contributory Factors Associated with Presence in Spatially Immersive Environments

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*** This paper is being updated - graphics and equations need to be added ***

Summary of Main contribution

There have been many attempts to define a straightforward definition for presence, largely without success. Indeed, it is tempting to try and derive a simple measure for the amount of presence a particular system is able to provide and then relate this to user task performance. Unfortunately, this approach is flawed because presence is a multi-dimensional parameter that is arguably an umbrella term for many inter-related factors. However, it is clear is that presence is a cognitive factor that must be treated differently than other aspects of a human-computer interface such as brightness or contrast of an image. By dealing with causal factors that affect user task performance and are related to achieving a sense of presence it is possible to understand the key contributory factors. This contribution will address the use of a VR Situation Awareness Rating Technique (VRSART) as a diagnostic tool for investigating presence and its effect on user/task performance. The following aspects will be addressed in this paper and subsequent presentation:

Main Report

Introduction

Perhaps the singularly most important features of a VR system compared with other human computer interfaces is its ability to create a sense of presence or 'being there' in a computer generated environment. Understanding presence could hold the key to the future development of effective virtual environments which facilitate intuitive interaction. By its very nature presence is a multi-dimensional factor that is highly dependant upon a number of factors. While other forms of media such as film and TV are known to induce a sense of presence, by far, the greater sense of presence is developed if one can interact with the environment in an intuitive manner. To describe this experience, terms such as immersion or presence are often used. Unfortunately, these terms are not interchangeable and mean quite different things. For instance, it is possible to be fully immersed in a virtual environment and yet, not feel part of it - because of the quality of the display and perhaps poor update rate. In the past there have been attempts to produce a single figure representing the degree of presence for a virtual environment and then relate this to some measure of human performance. Traditional evaluation techniques do not take into account attributes such as presence, greater interactivity and other important factors. This paper approaches the problem of understanding presence by addressing a number of significant contributory factors. This is driven by the need to derive a rating for the situation awareness that results from being immersed in a virtual environment. A special questionnaire (VRSART) has been designed to measure these factors according to the attitude and perception of VR users.

Rationale behind Situation Awareness and the Measurement of Presence,

Measurement of user performance in a virtual environment typically involves dealing with a range of measures including:- Objective measures (Task demands, Task results and correlated measures - error numbers, achieved task levels etc.), Subjective measures (on-line evaluations, post test evaluation questionnaires, explanation of high stress events), Psycho-physical measures (detection of the stimulus, recognition of the stimulus, stimuli discrimination, magnitude), Physiological measures (heart rate, blood pressure, respiration rate, ECG), Task performance and Learning efficiency. Unfortunately, presence does not have a single physical manifestation that can be measured objectively. This means it is necessary to derive a functional or parametric form for representing presence. The focus in this paper is the impact of cognitive function on presence. In particular, the demand on and supply of attentional resources to achieve a particular level of situation and spatial awareness. A simplified parametric equation for presence, can be summarised as :

$= (; ; ;_{d;} C; SA, SA; ; ; , ; ; I_{qty} ; I_{qual;} T_{e;; ; ,; dm;} t,t)$

where

Factors	Function
Demand of attentional resources	= demand on attentional resource
Supply of attentional resources	= supply of attentional resource = concentration of attention $_d$ = division of attention C = spare mental capacity
Understanding of situation	SA, SA = Situation awareness and change in situation awareness = understanding of situation = complexity of situation , = Spatial awareness and change in spatial awareness = familiarity of situation
Information	I_{qty}= information quantity I_{qual} = information quality $T_{e\ =}$ elapsed time in environment
Technological factors	= sensory modality

	= degree of immersion = field of view subtended by the participant's eye = field of regard of participant d_m = Display mode (binocular, monocular) t = update rate t = time lag (propagation delay between event and consequential action)

The above parametric equation does not take into account every factor that relates to the subjective feeling of being in a virtual environment. However, by assuming that a virtual environment is required to communicate information to a user who then is required to perform a series of tasks it is reasonable to look at the consequential demand on attentional resource and the supply of attentional resource. It is thus possible to make comparisons against task performance. Where the user is required to assimilate the information and understand the situation it is possible to begin to explore the user's situation awareness. This has been proven to be a very powerful indicator of cognitive performance in complex and demanding scenarios. The author has used such techniques in his earlier research on virtual cockpits. However, it is extremely difficult to measure situation awareness because of practical issues of when and how to take subjective measurements. Task related performance parameters can be collected on-line but these do not necessarily relate to cognitive performance or demand. A special technique has been developed which allows collection and rating of situation awareness, SA.

Description of the VR Situation Awareness Rating Technique (VRSART)

The mere process of collecting situation awareness data can have an interfering influence on a task if the data is collected during the trial. A technique once favoured, required the experimenter to stop the experiment at defined points and run a SA debriefing questionnaire. Unfortunately, this approach modifies overall task performance because the participant's cognitive loading is modified as a result of the interference. Instead, it has been found by experimentation that SA debriefing is more effectively run immediately after the trial. A programme of developing a reliable and robust method of eliciting SA measures is underway at the Advanced VR Research Centre. Phase 2 of VRSART is currently undergoing evaluation and forms part of a more extensive human performance in virtual environments research programme.

Objectives of the VRSART

The objectives behind the design of the diagnostic tool are:

1. To provide a sensitive computer based diagnostic aid to assist in relating task performance to the contributory factors that lead to a sense of presence,

2. To provide a structured method of determining the impact of presence on the efficiency of a spatially immersive VR system,
3. To partition presence factors into specific categories
4. To be a sensitive indicator of problematical areas of the VR user interface,
5. To provide immediate feedback on user performance criteria

Phase 2 VRSART

VRSART has been extended to address the correlation between demand/supply of attentional resources on situation awareness and the sense of presence. Although task performance is of primary concern the impact of secondary factors (such as situation awareness) on overall user performance is extremely important because it may be possible to tailor the virtual environment in such a way as to enhance situation awareness with a consequential improvement in overall task performance. Phase 2 VRSART deals with six principal factors:- demand on attentional resources, supply of attentional resources, Information, Understanding of situation, Presence and Technology Factors.

Demand

Demand on attentional resources - what percentage of resource were being demanded

Unpredictability of situation - to what extent was the situation unpredictable

Variability of influencing variables - an indication of how many variables were influencing the situation

Supply

Supply of attentional resources - what percentage of available resources are being supplied

Degree of readiness - readiness to deal with the situation

Concentration of attention - an indication of mental effort expended to deal with situation

Division of attention - percentage of attention time devoted to dealing with situation

Spare mental capacity - an indication of how much spare mental capacity is left to deal with additional tasks

Information

Quantity of information - how much content is being received

Quality of Information - goodness of information being received

Understanding

Understanding of situation - rating of degree of understanding

Previous experience - rating of familiarity of situation

Situation awareness - perception of complete awareness of situation

Complexity of situation - expression of how complicated the situation was

Familiarity with situation or previous experience

I felt isolated and not part of the virtual environment

I felt disorientated in the virtual environment

I had a good sense of scale in the virtual environment

Presence

I got a sense of presence (i.e. being there)

Technology Factors

The quality of the image reduced my feeling of presence

I felt a sense of being immersed in the virtual environment

The display resolution reduced my sense of immersion

A special computerised questionnaire has been developed so that subjective data relating to the above can be collected immediately after a trial and with minimum influence on the participant's subjective ratings. Other data relating to Technology factors (update rate, resolution, field of view etc.) are collected.

VRSART in the Context of an Evaluation

VRSART has been reliably used as part of the evaluation methodology shown in figure 1. It is not mandatory to follow this approach when using VRSART but if a quality evaluation is to be conducted then these steps are necessary to capture all the contributing human factors. VRSART must be administered immediately after the trial and before any subjective workload or usability tests have been conducted. Ideally, the participant should complete VRSART before leaving the experimental facility. In any subjective evaluation techniques the matter of delayed rating is very important.

Presentation and discussion of results obtained by VRSART

To be given at workshop

Known limitations of VRSART

As with any subjective measurement tool, care must be taken with interpretation of the results. Whilst it is possible to employ VRSART by itself it is much better to use it as part of an overall evaluation programme where other user performance data (typically, usability VRUSE, Task workload, Context Analysis, task performance, etc.) is collected. This makes it easier to relate any unexpected results with other quantitative data. Comparison of VRSART data with other data can be problematical if the analysis is performed using a spreadsheet package such as Excel. It is considerably easier to employ a statistical analysis system such as SPSS or Statistica (the author's choice). Apart from these operational considerations VRSART can be a very useful diagnostic tool in the development of spatially immersive interfaces.

Verification programme

The validation of any human factors tool is a laborious process necessitating a range of trials and repeat trials until statistical confidence is reached with the technique. VRSART is undergoing development and is being applied to a range of scenarios. The resulting data will assist in the evaluation of the technique's robustness and evaluation. A formal evaluation methodology and protocol has been developed to ensure that the technique is administered in a systematic and consistent manner. All evaluations are subject to a detailed Context analysis to ensure selection of suitable performance metrics.

Discussion

Effective development of human-computer interfaces for virtual realty (VR) is critically dependant on robust design methodologies and human performance metrics. From a user's perspective human performance is a significant factor and if poorly implemented can lead to an unacceptable system. By measuring the user's situation awareness with the interface it is possible to identify shortcomings in operation. To date, the majority of human factors research in VR has concentrated on health and safety aspects or on more fundamental human factors issues of perception and empirical performance. Unfortunately, relatively little research has been undertaken on the situation awareness provided by a VR system. Designers and developers of VR systems will find VRSART an extremely powerful diagnostic tool and will be of value to anyone who is producing VR interfaces because it provides a wealth of information about a user's viewpoint of the interface.