Cognitive presence as a unified concept of virtual reality effectiveness

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1. ABSTRACT

We propose a synthesis of two current major approaches to understanding the effectiveness of VR systems. We propose cognitive presence as a single, unified concept of presence which includes previous ideas of presence in a cognitive psychological framework, and propose a methodology for measuring it. We then critically examine the notion of cognitive presence, as a way of conceptualizing HCI quality in virtual environments.

2. KEYWORDS

Categories and Subject Descriptors: I.3.7 [**Computer Graphics**]: Virtual Reality.

General Terms: Human Factors, Theory

Additional Key Words and Phrases: presence, cognitive psychology, effectiveness of virtual environments.

3. CURRENT IDEAS OF PRESENCE

Presence is currently the focus of much VR research. Many researchers believe that presence can be used as a general measure of VR effectiveness ([21], [10]), and that creating VR systems which increase presence in users will contribute towards better task performance on those systems ([10], [13]). Presence is currently of interest to a wide variety of researchers, ranging from those who are interested in how display technologies are related to presence (for example, [12], [17] and [1]) to those who are interested in the human interface aspects of VR (for example [10],[11], [15] and [19]).

This brief paper does not pretend to be a comprehensive review of presence research philosophies (see [18] or [20] for such a review). Rather, we suggest that many current ideas about presence can be divided into two broad categories: an introspection based approach and a postural or movement approach. For the purposes of this classification, we define presence simply as "the extent to which the virtual environment has an appropriate effect on the user".

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The first approach to presence we identify is that which places emphasis on sensations or other subjectively rated internal states. The best known example of this approach is probably that proposed by Sheridan [10], [11] and extensively applied by, for example, Slater, Usoh & Steed [13] and Usoh et al [19]. The most apparent characteristic of this conception of presence is its focus on internal states, and the use of introspection by the subject as a means of detecting and scaling presence. This is the strength of this approach - its recognition of the private and internal aspects of presence. However, its central weakness lies in the difficulty associated with identifying and measuring such internal events, and its reliance on introspection (see [5] for an overview of the limits of introspection). The second approach to presence (which has been referred to as "behavioural presence", although it focuses almost entirely on movement and spontaneous speech) focuses on identifying presence via observing bodily movements or posture changes in subjects. The implicit theory is that postural changes (a "real environment event") will only occur to a "virtual environment event" if the subject were highly present (i.e. when the real and virtual worlds became blurred for the subject). For examples of work using this idea, see [17], [15] and [7]. The strengths of this approach lie in its emphasis on observable phenomena (reducing much of the uncertainty and unreliability associated with introspective measures of presence) as well as having a clearly defined criterion for identifying presence. Its weaknesses include a lack of sensitivity and an exclusion of more subtle effects of presence; only subjects that are present enough to move in response to virtual stimuli are considered present.

4. UNIFYING PRESENCE

It appears that the two approaches to understanding presence we present above are divided by a wide chasm, although they both clearly include aspects of presence (in the larger sense) that are important. It is widely recognized that both of these approaches are important, and this is indicated by the growing number of researchers who include them both (see [19] for an example). If it is the case that these two seemingly different approaches tap into the same phenomenon (that is, presence), then it can be suggested that each of these current approaches are specific cases of an unspecified, more general, approach to presence. We suggest that this more general approach to presence (which we call "cognitive presence"), includes aspects of both the previous approaches, as well as other, as yet undiscovered hypothetical facets of presence. The test of whether cognitive presence is a super-ordinate construct to the previous two approaches will lie in its ability to explain and include these two approaches completely.

5. COGNITIVE PRESENCE

We believe that a more general concept of presence is one which focuses on the impact of the virtual environment on the user's overall state of mind, rather than only on observable movement. Also, we believe that it is more useful to focus on the effect of the virtual environment on cognition rather than simply focussing on the sensations produced by the VE. We call this conception of presence cognitive presence.

5.1 Definition

Cognitive presence is the degree to which the virtual environment dominates over the real environment as the basis for thought. This includes only the abstract notion of the virtual environment (rather than the virtual reality system), and not the technology used to display it. In line with current research, we consider the display of an environment to be a determinant of presence (see [17], [12] and [1] for examples), and as such we do not include them in our definition of presence. This is necessary so as to avoid the creating a vacuous concept. For example, we can define presence as "the experience a user has when viewing a VE under certain display criteria", but this definition removes the need to research presence, as it already implies what is necessary to bring about presence, and excludes other possible ways of arriving at presence; presence simply becomes a shopping-list of display criteria. We consider the display of a VE as an interface issue, such that certain displays provide better information about that environment, and we agree that different presence levels may result from different display systems. However, we do not wish to exclude the possibility that presence may arise from unforseen sources, or from unexpected display systems, such as text-only or audio-only displays.

We define a *virtual environment* as a set of data displayed in such a way as to create in users the impression of objects in a space. For the reasons mentioned above, we do not limit the type of space or data which may bring about presence, but rather leave that as a question open to investigation.

Our emphasis on the VE as the preferred or dominant basis for thought (which can also be referred to as the cognitive dominance of the virtual environment) is the key to the concept of cognitive presence. Cognitive dominance is the state where thought is more aligned with and appropriate to the virtual environment than it is with the real environment, and can occur in degrees. Cognitive dominance of the VE has several important implications. For instance, if the VE is dominating cognition during the time of the experience, then memories for that time period will be of the VE rather than of the experimental setting, as few cognitive resources were available to encode memories of the real space. Problem solving strategies will be in line with the virtual environment rather than the real environment, as VE related strategies will be primed by the VE rather than by the real environment. A user in a state of cognitive dominance will tend to respond to events in the virtual environment in ways which are appropriate to the VE rather than to the real world, also due to priming by the VE. Motions will be initiated as a response to the virtual world rather than to the real world, and so on.

It is important not to confuse "dominance over cognition" with "focussed attention". Focussed attention has been shown to be an important aspect of presence [4], and we do not dispute this. However, attention functions simply as a filter which controls the data upon which cognitive processes act [9]. Cognitive dominance includes the notion of the virtual environment not only being the main source of data for cognition, but also as being the main determinant of which *rules* are selected to process that data. One can imagine a user who is completely focussed on a virtual environment reacting to a virtual missile flying towards her by moving the mouse. Although her attention is focussed, cognitive dominance has not occurred. A second hypothetical user might react by ducking (thus showing more presence). This difference cannot be accounted for in terms of cognitive data alone (both users had the same data), although it can be explained in terms of rule selection. The first user selected a "real world aligned" rule, where ducking is only appropriate to real-world missiles, whereas the second user has selected a "virtual world aligned" rule, where ducking is appropriate for virtual missiles.

It may seem to some readers that cognitive presence is quite similar to the postural/movement approach described in section 1 above. This is in fact the case, although there is one important difference. Whereas the postural approach focuses on observable movements of the body, cognitive presence deals with the cognitive processes which underlie not only movement, but cognition as a whole. Thus, cognitive presence is concerned with more subtle effects of the virtual environment on the user, among which are possible subjective sensations and other internal events. If a user is not moving in a way consistent with the virtual environment, it is still possible that the VE is having some internal effect on that person. Cognitive presence is also able to cope with effects on the user which are not generally observable, such as emotional changes.

It can be argued that the position presented in this paper is that the sole purpose for creating virtual environments is to produce presence. Many virtual environments do not aim to, nor require, the production of presence in their users (for instance three dimensional visualization systems, or simulations of physical systems). We do not agree with the position that all virtual reality systems should have the production of presence as a stated aim in their specification. However, we do suggest that quite often one of the outcomes of presenting data to a user in such a way that it suggests to the user that they are inhabiting a space *is* presence, whether this is intended by the systems engineer or not. If this is the case, then understanding the effect which presence may have on the user becomes as important as understanding the effect which the chosen user interface may have on the user, as this effect may lead to a change in performance in use of that system. For this reason, we feel that understanding presence is of interest to all members of the virtual reality community.

5.2 Measurement of cognitive presence

Measuring cognitive presence poses an interesting challenge. Determining if the VE has become the basis of thought cannot be done directly. This is because cognitive dominance is not an effect of the contents of thought, but rather the rules which are applied to them. As these rules are generally automatic, they operate below the level of consciousness, and introspection methods such as the breaks in presence method [14], or questionnaires (such as used in [20] and [12]), are not applicable. Also, as the effects of interest are only sometimes

externalized into movement, postural measures (as exemplified by [7]) are not general or sensitive enough. Because the point of interest is the operation of rules rather than data, we propose to examine the bias in processing which is the signature of cognitive dominance. If the virtual environment is made to be dangerous, and it is effective, then fear and vigilance should be evident as a bias in processing of *all* data. In our measurement approach, we present users with a series of ambiguous stimuli, and ask them to make some sort of simple decision or identification task. We then examine the series of responses, looking for a pattern which indicates a bias in the responses. The specific tasks for the subjects can take several forms.

One method of measurement is to show an ambiguous word or word fragment, and ask the subject is to identify which word it was (with the cognitively present subject predominantly selecting words which are aligned to the VE). For example, to test cognitive presence in a medically aligned VE, one might briefly flash the word "N***LE", and then ask the subject to state what they saw as a forced choice response from the list NOODLE, NETTLE, NESTLE, NEEDLE. We would expect the more cognitively present subject to select thew word NEEDLE, which is more aligned to medical themes than the other options. A second option is by looking at the patterns of inference made by subjects, as the influence of cognitive presence should also extend into inferences. For instance, users can be asked to speculate as to what is behind a locked door in a virtual building. In a medical VE, for example, cognitively present subjects would infer that behind the locked door is some sort of medical paraphernalia or procedure occurring. Subjects which are not cognitively present will tend to make inferences which are either random in theme, or aligned to the real world rather than the VE.

By administering a long series of these items (interspersed during the VR experience), and looking for consistency or pattern in the responses of the subjects (perhaps by means of a goodness-of-fit Chi square analysis), we can measure the degree of cognitive presence in that user. This method is attractive as it is almost completely objective (requiring little interpretation by the subject or researcher), is simple to model statistically, and is also not as open to demand characteristics effects as introspective methods which are currently used (for instance, [20] and [13]). Also, unlike the "breaks in presence" approach [14], this method does not impose two simultaneous tasks on the user (performing the experimental task and remembering to report breaks in presence), and as such should not lead to as many under-estimates of presence level.

6. CRITIQUE OF THE COGNITIVE PRESENCE APPROACH

The cognitive presence approach conceptualizes the effects of the virtual environment on thought processes. This level of abstraction permits one to try to explain current presence findings from a unified perspective. For instance, the presence findings based on perception, such as those by [1] and [8] are currently separate from those based on posture and movement. Approaching these from the perspective of fundamental cognitive processes, it might be possible to find a framework or theory which explains both of these styles of finding and how they relate.

The cognitive presence approach is quite general, to the point that some presence researchers might be uncomfortable with its inclusiveness. For instance, under the definitions presented in this paper, a WIMP interface (windows, icons, mouse and pointer) with a strong desktop metaphor could be thought of as producing presence; a space is represented, and if the user thought of the desktop as a real desktop (as intended by the metaphor), then this could be correctly identified as a virtual environment which can produce cognitive presence. We do not consider this a weakness as such, as there is not firm evidence that non-3D environments may produce presence, but as it is a contentious issue, we include it as a possible weakness. A second weakness of this approach is that it does not explicitly include a notion of interaction, which is seen as central by some researchers (see [21]). However, we feel that there is not enough evidence in favor of interaction as a major determinant of presence to regard interaction as a necessary condition for presence at this stage.

6.1 Cognitive presence as a measure of the HCI quality of VE applications

The "high level" nature of cognitive presence does not allow one to make direct HCI predictions about the specifics of VR interfaces. However, cognitive presence creates some interesting implications for HCI issues in VR. Specifically, the definition of cognitive presence implies that a highly present user will be strongly focussed on the VE, and thus applications which require a lot of concentration on the task will be improved if they are expressed in VEs which create a high degree of cognitive presence. In such an application, the measure of cognitive presence can be taken as a (highly indirect) measure of usability. A second implication is that VEs are not necessarily always an appropriate way to represent a task. Each task has specific cognitive demands, and if the VE is not aligned to these demands, the VE will reduce the amount of cognitive resources available for completing the task. This implies that the selection of the VE that the task will appear in is important with regards to the performance of a user on that task.

Generally speaking, presence (including cognitive presence) is a more effective criterion measure than it is a usability measure – it allows one to test if the VE is having the appropriate effect on the user, but not if the application's interface is optimized by implementing it as a VE. The HCI demands of VR systems, such as navigation and object manipulation, still require separate investigation. However, the issues of VR usability are not completely independent of presence. A frustrating interface which requires great mental effort to use will reduce the amount of cognitive resources which are available for cognitive dominance and thus reduce cognitive presence. If the relationship between presence and VR HCI is examined by means of thought experiments, it does not seem to be symmetrical – a good interface will not ensure high presence, although high presence levels seem to imply that the interface is not using a lot of cognitive resources. As there exist no theories of the cognitive mechanisms of presence, these types of questions can only be satisfactorily answered by means of empirical validation.

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