Immersion and Presence

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Abstract: In a Virtual Environment (VE), ***Immersion,*** defined in technical terms***,*** is capable of producing a sensation of ***Presence,*** the sensation of being there (part of the VE), as regards the user (Ijsselsteijn & Riva, 2003). Presence is indeed, historically, at the core of Virtual Reality (VR). Presence has often be conceived as a sign of "ecological validity" of VR devices, also as a sign of potential positive transfer of skills or knowledge learned in a VE to the real world.

1- Immersion and Presence

Virtual reality technology does allow users to have unique experiences, such as standing inside a molecule or foresee a future vehicle's interior before production has even started. In this sense, VR (and more generally computerized devices) really acts as a problem-solving device, transforming enormous quantities of mind-breaking data into "graspable illusions" [1]. In this sense, Rheingold [2] draws a naive history of computers. He particularly shows that, from the beginning, computers were conceived as "mind-amplifying" devices, helping the human operator process complex data . He also shows that a decisive step was made when researchers had the idea to connect a television screen to a computer, then a keyboard and a mouse, instead of having punched cards as inputs and number on a sheet of paper as output [3].

In this sense, the primary characteristic distinguishing VEs from other means of displaying information is the focus on **immersion.** In a technical acceptation of the term, immersion is achieved by removing as many real world sensations as possible, and substituting these with the sensations corresponding to the VE. Immersion is by essence related to the multi-modal nature of the perceptual senses, and also to the interactive aspects of a VR experience.

From this viewpoint, immersion is intuitively related to the resemblance of the VR devices with human characteristics. These include the size of the human visual field, the stereoscopic aspects of the simulation, the "surround" aspects of the sound, that is the extent to which the computer displays are extensive, surrounding, inclusive, vivid and matching. The term 'immersion thus stands for what the technology delivers from an objective point of view. The more that a system delivers displays (in all sensory modalities) and tracking that preserves fidelity in relation to their equivalent real-world sensory modalities, the more that it is 'immersive' [4].

From this technological standpoint, immersion is intended to instill a sense of belief that one has left the real world and is now "present" in the virtual environment. This notion of "being present" in the virtual world has been considered central to VE [5]. Thus, whereas immersion is a "technology-related", objective aspect of VEs, presence is a psychological, perceptual and cognitive consequence of immersion. Presence is thought of as the psychological perception of "being in" or "existing in" the VE in which one is immersed [6-9].

To date, the utility of the presence construct, either to enhance interactive design or human performance, is not clearly established. In fact, the most direct evidence for a positive role of presence in the efficacy of VR comes from therapy applications of VR [10, 11]. Before discussing more precisely the potential interests of the quest for presence in industrial applications, we would like now to draw a current state-of-the-art of current measures of presence, which will eventually clarify a little the concept itself. We will retrain our discussion to the (initial) concept of spatial presence (i.e. self-orientation and self-location with respect to a media environment, not the real environment). One has certainly to recognize that, beside spatial presence, social presence is certainly something users of VE (and more generally video games) are looking for. Social presence is defined as the sensation of interacting with other forms of intelligent agents in the VE [12]. It is in particular related to the presence of avatars in the VE, which is obviously part of the future developments of VR, and beyond the scope of this manuscript. We will thus use hereafter "presence" to mean "spatial presence".

2- Measuring Presence

2.1- Questionnaires and subjective measures

In the 90's, researchers in the field of VR have developed questionnaires, trying to evaluate the subjective degree of presence [13]. Interestingly, these authors refer to presence as a “psychological state experienced as a consequence of focusing one’s energy and attention on a coherent set of stimuli”. In this definition, two points are mainly relevant. First, the "coherent set of stimuli" is a reference to the immersive characteristics of the VE (high fidelity graphics and sound, interaction, …, with the general assumption that the more senses are stimulated and the more interaction in the EV, the more Immersive is the VE). Secondly, the focus is clearly put on cognitive processes, such as attention and situation awareness [14]. Indeed, Prothero et al. [15] argue that presence and situation awareness are related, since they both imply that observers perceive their self-location and self-orientation with respect to an environment. Presence can thus be defined as a special case of situation awareness, in which self-orientation and self-location are defined with respect to a media environment, not the real environment.

In this conception , most of the questionnaires used to a access presence are using Visual Analog Scales, asking the subject to rate dimensions such as degree of control, sensorial immersion or realism (figure 1).

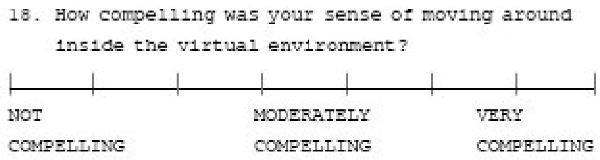

Figure 1. An exemple of Visual Analog Scale. The subject is asked to rate his/her sensation on a 7-step scale, with opposite descriptors at each extremity of the scale (adapted from [13])

More precisely, Witmer & Singer [13] first systematized this methodology. They first suggested that presence was dependant not only on immersion [16], but also of the user's involvment (defined as "a consequence of focusing one's energy and attention on a coherent set of stimuli or meaningfully related activities and events" [13]). Witmer & Singer list 4 categories of factors susceptible of contributing to the sensation of presence: Control factors (dealing with the user's interaction with the VE), Sensory factors (various aspects of the sensorial stimulation, such as multi-modality), Distraction factors and Realism factors. Whereas the first two factors are mainly objective aspects of the VE, the last two are related to both objective and subjective determinants. For instance, Distraction factors include selective attention and Realism factors include the "meaningfulness of experience", which itself refers to the user's previous experience with the situation, among other factors.
From this framework, the authors build 2 questionnaires: The Presence Questionnaire (PQ), which directly measures the degree to which subjects are sensitive to the factors presented above see figure 1, for example), and the Immersive Tendencies Questionnaire (ITQ), which tries to evaluate their tendency to become involved or immersed. In the ITQ, questions like "Are you easily disturbed when working on a task?" are presented.
Obviously, such questionnaires are introspective, "post-immersive", tentative evaluations, and one might argue that they measure more of the subject's perception of the system's properties than presence per se [17, 18].
These questionnaires are certainly valuable, notably given their ease of use and the fact that they do not interfere with the user's experience while in the VE. They can be however be criticized, mainly because they do not clearly define what they are supposed to measure. Another inherent problem is the fact that they are insensitive, by essence, to time-varying qualities of presence during the exposure itself. In this matter, Slater & Steed [19] introduced a methodology, based on the idea that presence is by essence a bi-stable phenomenon, the subject oscillating between feeling "in the real world" and "in the virtual world" (due to various factors, such as temporal delays or poor realism in the VE). These authors thus designed experiments in which users had to report "breaks in presence".
However, they can be used in conjunction with other measures, such as the subject's behavior and /or performance in a VE, as well as physiological measurements. This point is notably emphasized in [20], noting in particular that body movement have to

be coherent with the spatial structure of the environment the subject experiences as "reality".

2.2- Physiological measures

To pursue a little on Slater and col. work, a famous experiment of this group involves a "pit room". In this "pit room" (figure 2) the participant walks into a virtual room with an 18m precipice at its center. In fact, the person stands and walks in a CAVE™ [21] system, in which a wooden ledge is positioned at the place where the virtual edge lies in the VE. This meant to corroborate visual signals, indicating that they are standing in a room with a dangerous precipice.

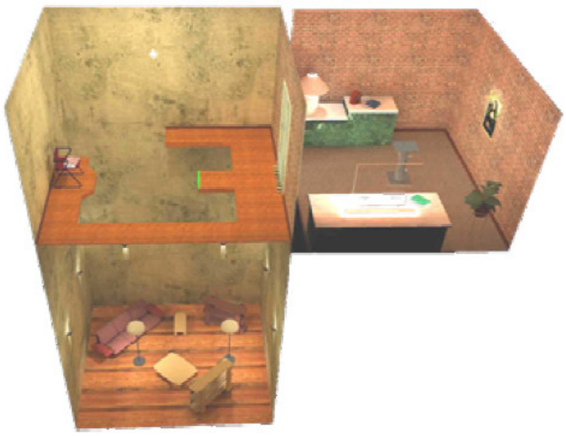

Figure 2. The "visual pit" virtual environment, with the "pit" on the left and the "training" room on the right.

Slater [20] interestingly note that heart rate increases when subjects reach the virtual precipice, suggesting that physiological measures might be an indicator of presence (see also [22]).

Indeed, a number of physiological indicators including skin conductance and temperature, muscular tension, cardiovascular responses, and pupilometry have been suggested as presence measures [18]. The idea is that these indicators can deliver continuous information regarding the effects of specific environmental stimuli or events experienced in a VE. For example, Strickland and Chartier [23] illustrate the feasibility of recording EEG (electroencephalogram) signals in a head mounted display. Measuring and interpreting the differences in cortical responses in real and virtual environments may lead to a better understanding of the effects of various software and hardware influences in a virtual environment. For example, change in heart rate measures the increase or decrease in the number of heartbeats per minute, and can be quite easily measured with an electrocardiogram (ECG). Skin conductance changes when sweat is produced in the palm of the hand, and is commonly associated with stress and reaction to unexpected stimuli.

These measures are now widely used, in connection with subjective ratings of presence [22, 24]. For example, Meehan [22] used heart rate, skin temperature, and galvanic skin response in the "pit room" experiment (figure 2). He showed that the

physiological measures reliably distinguished between the training room (visually safe) and the pit room. Recently, studies have started using fMRI (functional magnetic resonance) to study brain activity associated to the sensation of presence [25].
For now, it appears that valuable information can be collected using physiological signals. However, beside the fact that some methods might be intrusive and/or relatively unreliable, it seems important to distinguish two levels of analysis. In Meehan's study [22], average heart rate is compared between the time the subject is in the training (control) room and in the pit room, and results are quite clear. However, this is quite a large temporal-scale level of analysis. It might be interesting to try to go down to a more fine-grained temporal level of analysis.
This is especially important when one wants to correlate physiological data with actions or events in the VE. And this is where things get more complicated to analyze. Many events (internal and external) can affect a person’s heart rate, for instance: stress, fear, exertion, emotion, etc. Heart increases when a person is under stress. Heart rate is also affected by emotions, by unexpected stimuli, … Nevertheless, for validity and usefulness, one would like to correlate events happening in the VE with changes in physiological signals. In other terms, an event-related analysis is required. It appears that things are not there yet, although moving in this direction. This is an important issue, since physiological data appear as an objective indicator, which has to be related to behavioral data, in order to be fully functional in the evaluation of presence, notably in relation with the subject's performance in the VE.

2.3- Behavioral measures

2.3.1. Performance

Intuitively, it seems reasonable to assume that the more present a user is going to feel present in a VE, the better his/her overall performance. However, things are not so straightforward, notably due to individual skill variability.
In first instance, this assumption has been directly tested in a number of tasks, in which subjective ratings of presence appear to be positively correlated with performance. These tasks include tracking behavior and visual search tasks in immersive VE [26]. However, in a significant number of studies (for example [27], using a three-dimensional chess involving spatial skills), performance is not systematically related to presence. Slater & al. state " The issue is not really that of whether presence itself enhances performance. For example, an individual's performance in word processing is usually superior using a modern point-and-click user interface than under UNIX using "vi" not of course because of presence, but because of the former superior user interface. In our view presence is important because the greater the degree of presence, the greater the chance that participants will behave in a VE in a manner similar to their behavior in similar circumstances in everyday reality. Hence if an IVE is being used to train firefighters or surgeons, then presence is crucial, since we want them to behave appropriately in the VE and then transfer knowledge to corresponding behavior in the real world". We will come back on the key question of transfer later.
For the moment, we retain from this first survey, that behavior might be more important to investigate than strict performance per se, which might be too dependant on external (e.g. interface) or internal (e.g. skills, experience) factors. Let

us thus turn onto behavioral analysis, starting with rather low-level behaviors, which are nevertheless worth mentioning.

2.3.2. Reflexive Motor Acts

Simple behaviors may show participants feel as if they are in the virtual environment. They may include reaching for a virtual object, socially reacting to avatars, turning away or closing the eyes when presented with an approaching object, and startle responses [28, 29]. These reflex-like responses could provide indicators of presence in a VE. For instance, in the "pit room" mentioned earlier (figure 2), the fact that users walk carefully when close to the visual cliff seems a reasonable indicator that they feel present in the VE, rather than in the flat CAVE environment.

Slater et al. [30] conducted such a study in which participants were shown a real radio, then entered the virtual environment with a radio at the same location. During the experiment, the real radio was moved and turned on, and the participant asked to point to the location of the radio. The more present the participant, the more likely he would point to the location of the virtual radio rather than the real radio. They found a significant correlation between this behavioral measure and a presence questionnaire. Such methodology is particularly interesting, since it addresses directly the question of the bi-stability of the sensation of presence (between real and virtual worlds).

A similar approach has been tried by Prothero and col. [31], looking for a possible relation between vection and presence. Two experiments examined the hypothesis that "presence" is enhanced by manipulations which facilitate interpreting visual scenes as "background.". Along this line, Freeman et al. [32] have tried to measure the relationships between presence ratings and motion-induced postural reactions. They measured the degree to which participants swayed back and forth while watching a video shot from the hood of a rally car . They particularly considered situations in which the subjects saw the video either monoscopically or stereoscopically. There was a positive effect of stereoscopic display on the magnitude of postural movement. In the same time, subjective measures of presence were also higher for the stereoscopic presentation.

All these behaviors are however quite simple, reflex-like sensori-motor coupling, which might even not be specific to humans (for example, closing one's eye in response to an approaching object). This mention is not to deny their undeniable interest in presence research. We might nevertheless want to consider more integrated, skillful behaviors.

2.4- Sensori-motor control

While looking at the presence "problem" from a more integrated behavioral point of view, we still want to stick to this general idea, well expressed by Slater [20], talking about the "pit room" experiment: "Presence in the virtual room at any moment results in choice of the hypothesis that indeed this is a room with a precipice rather than the physical place of the CAVE. Of course the participant has abstract knowledge that ‘really’ they are in the CAVE. But visual perception overrides this knowledge and the bodily system reacts as if they were in the pit room - heart rate rises, *locomotion is carefully judged*, the subject reports symptoms of anxiety (italics added)". Two points have to be noted here. First, what does "locomotion is carefully judged" exactly mean. Obviously, a simple rough performance evaluation is not enough here. The analysis of locomotion has to be carried out at the sensorimotor coupling level. Secondly, the idea is always that the subject's behavior, here locomotion, resembles the behavior he/she would exhibit if there were a real cliff in the real world. This is precisely here that the research on presence in VE interacts with behavioral neurosciences, since a precise analysis and modeling of sensori-motor coupling is required.

One first example of such behavior is oculomotor behavior. Ocular behaviors have long been suggested as presence measures [33]. Measures of visual system behavior may provide a wealth of information regarding attention, alertness and arousal., eye-trackers, and electro-oculograms (EOGs) have the potential to be useful tools in the isolation of presence invoking stimuli. These visual indicators may serve to identify which elements of the VE capture attention (see also [34]). In this field, Duchowski [35] has accomplished a lot, adapting eye tracking systems to VR and also promoting the use of oculomotor behavior analysis in VR training [36, 37].

The second example comes from recent research we have conducted in the field of teleoperation. In VR, it is often accepted that the goal is to have the subject behave as naturally as possible (hence the concept of natural "transparent" interfaces). Without going here into this difficult problem (which is related to the learning and adaptive processes involved), let me mention recent work in the field of mobile assistance to handicapped people [38]. The goal was to evaluate how an operator "incorporates" a distal tool (here a mobile robot) into his/her body schema (cf. the concept of tool appropriation). We evaluated different solutions for the control mode of the robot. In short, we found that when the robot's control modes followed "natural" visuo-motor anticipatory mechanisms, sensori-motor invariants observed in human behavior emerged in the robot's trajectories (like the relationships between the speed and curvature of a trajectory). Following this, we suggest that the observation of "natural" sensori-motor invariants in VEs can be a marker for presence.

One interest of this tentative methodology is that it enables us to use the possibilities offered by VR technology to manipulate, analyze and model the determinants of such invariants. This approach might also help clarify the concept of "behavioral realism". Finally, we propose that the focus on the quality of sensorimotor control in VE might first contribute to deliver a more objective measure of presence in VEs and secondly to make presence an important goal in transferring VR application data to the "real world".

3. Implications for real applications

So far, we saw that presence is approached from many perspectives, from introspective post-hoc questionnaires to on-line evaluation of sensori-motor coordination. Obviously, research on presence itself is still in its early ages (it started really about 10 years ago), and the reason dictates that all these measurements be intermixed, until further conceptual advances.

The real question is the utility of presence when it comes to decide whether users' experiences in VR have some validity in real life. This is especially true in domains such as training, learning and industrial design.

Starting with training, it is evident for a long time (when virtual environment were still called simulators) that it is important to let novices experience situations which might be fatal in real life. It is thus intuitively clear that the more involved (present) a subject will be in the VE, the more chances exist that what he learns in the VE will be transferred later in real life. This is true when the "teacher" works at a semantic level, when he/she wants the novice to understand why a given situation has to be dealt with in a given way. In other terms, we are here at a relatively global level of task analysis.

If we go down to a more local level of analysis of the skill(s) associated to a given task, things surely get more complex. In particular, this is where interfaces come into play, where realism becomes important. For instance, it might be that the user feels perfectly present in the VE, and that he/she performs optimally in the VE. It might however be that the VR device is setup in such a way (due to interface or sensorial design) that the skill the novice learns in the VE has nothing to do with the skill that is needed in the real world. This is one of the reasons why we believe that focusing on sensorimotor behavior and invariants (and not on interfaces) is one to try to maximize the chances of good transfer.

The same global discourse is applicable to design. It is true that VR has enabled, due to computer power and advances in sensorial (e.g. high spatio-temporal resolutions) and input (e.g. haptic) interfaces to represent incredibly complex amounts of data and future projects. The decisive question is: If I validate this project during a VR experience, am I certain that the real outcome will be conform to what I perceive in the real world? This problem is complex because simplification or distortions (voluntary or not, due to the technology, …) might have been present in the VE, upon which I based my judgment.

All these partial arguments are meant to provoke a discussion in professionals, who feel the power behind virtual reality and are, in the same time, conscious of the potential dangers in trusting blindly virtual worlds, which appear yet more like "playgrounds" than "commongrounds". We suggest that concepts like immersion and presence, while deserving research work, are useful in the process of bringing VR to a more mature state, since they force us to focus our attention on the user, in psychological and human-machine communication (interface and interaction) terms.

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