Study of an Interactive and Total Immersive Device with a Personal 3D Viewer and Its Effects on the Explicit Long-Term Memories of the Subjects

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Abstract. We studied an interactive (functional and intentional interactivity) and immersive (technical and psychological immersion) device with a personal 3D viewer (360° vision and environmentally ego-centered) and its effects on the explicit long-term memories of the subjects (4 groups of 30 students for a total of 120 subjects) (2007 and 2012).We have tested memory, communication and feeling of presence in our virtual environment with a canonic test of presence (Witmer and Singer, 1998). This article is a reflection on these 3D devices and their impact on the long term memory of the students, and on their presence sensation.

1 Introduction

Observing the virtual world is a stage that allows us to prepare ourselves for other actions and that is necessary for understanding the virtual world. Navigating, acting and communicating presume an action on the user's part. The structure of our experiment can thus be considered as interactive in the sense that it allows the user to perform these four actions. We can therefore describe the structure of our experiment as an immersive, interactive structure, giving the sensation of presence. We must too describe the type of memory that we have tested in our experiment and, for that purpose, call on the theories inherent in the memorization processes within the learning programs, notably in the domain of cognitive sciences. Our experiment entails a 3D device in the setting of media-based, educational communication. Our initial hypothesis was calling upon an increasing number of sensory modes simultaneously makes it possible to increase performance of the long-term explicit memory of the information delivered by the didactic content (Paivio, 1986 and 1991), double coding theory (Paivio and Caspo 1969). As far as our experiment is concerned, we have tested long term / explicit memory. In fact, that is the form of memory at work when memorizing a course, even if learning brings several forms of memory into play. We begin by defining our framework by distinguishing immersion, interaction and feeling of presence. In a second part, we define the different types of memory to explain what sort of memory we have tested in our experiment. In the third section, we describe our protocols of experiment. In the fourth part, we give the results of our experiment.

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2 Framework

2.1 Virtual Reality

The notion of Virtual Reality (VR) has given rise to many definitions in the literature. In 1986 Jaron Lanier used the term « virtual reality » (VR) for the first time. He defined it as being a reality:

- that we can apprehend through our senses,
- with which we can interact,
- that can be synthesized and shared with other persons,
- which does not affect our individuality but only our senses.

There are two types of approaches to VR: a psychological approach and a technical approach.

1. The psychological approach to VR emphasizes its sensory and cognitive aspect: «V*R is above all a mental construct formed by the observer when confronting sensory stimuli that have been supplied to him by technological devices.* » (Schneider, 2001).
2. The computer science specialists, in turn, choose a technical definition of VR and are interested in it as an interface: «*VR is an immersive experience in which the users wear screen headsets provided with position sensors, see stereoscopic images, hear 3D sounds, and can explore an interactive world in three dimensions*» (Pimentel and Texeira, 1993).

The last definition suggests that VR in a 3D context necessarily presumes advanced technology. In fact, the equipment used is made up of a work station (PC unit or Silicon Graphics station and a monitor), plus components for data retrieval and capture:

- Stereoscopic vision headset or vision helmet.
- Spatial position tracker or detector necessary for the computer to integrate and analyze the representation of the human body and its numerical model, its position, and its movements.
- A stereophonic sound retrieval system for reproducing 3D sound effects.
- An array of interface variables: joystick and other secondary accessories, vibration suit, dynamic chair…

Therefore, these definitions presume that Virtual Reality is inherent in the 3D image. Now, certain researchers oppose this understanding. For example, Daniel Schneider, psychology and education sciences professor at the University of Geneva, thinks that a 2D or text environment is enough to immerse the user in VR.

We can reach a consensus on the definition of Virtual Reality: a system which gives its users the sensation of presence in virtual spaces and allows them to interact with the system's components. The notion of Virtual Reality is therefore inherent in that of immersion which we must now elaborate.

Immersion. Many authors have likened this term to a technical notion which might act on the user's senses.

Cadoz (1994) asserts that immersion is «*a technology, an interface technique between man and machine and does not involve the psychological state of the subject*». The physical immersion of a subject in a virtual environment is performed by sensory information (sight, hearing, etc.) alone.

For Pimentel and Texeiria (1993), immersion is «*the state of a participant when one or more of his senses… is isolated from the exterior world and he no longer registers any information that does not come from the computer*».

According to Seipel (2003), a virtual environment is considered :

1. ***Immersive*** when the totality of the user's senses is called upon on the one hand, while on the other hand there is total immersion of each sense (even if this total immersion is seldom attained in practice).

   According to Slater and Usoh (1993) and Slater and al., (2001), in an immersive environment, the users have an:

   - **egocentric** view of the virtual world, that is, a view from the inside of the environment or of the phenomenon, as opposed to an:
   - **exocentric** view from the outside of the environment, where the user does not directly take part in the virtual world. For systems of these types, immersive technologies are used: data gloves, CAVE or HMD headsets, etc. Technologies of this kind allow visual immersion of the user in a virtual environment.

2. ***Semi-immersive*** when users can interact with both real and virtual worlds at the same time. Semi-immersive technologies utilize fixed visualization systems covering a large part of the visual field or going beyond it, these systems generally originate in simulation systems (Kalwaski, 1993). They cover a field of vision of 130 degrees. With semi-immersive technologies several persons can interact on the objects. An example of this kind of environment would be the systems used in artificial reality, such as «responsive workbenches» or projection rooms.
3. ***Non-immersive*** is when one uses a «desktop» display (Psotka and al., 1993). These are generally computer screens. This kind of VR reduces the user's contact with the virtual world to a window. This does not give the sensation of being present but simply of being in contact with a virtual environment. These worlds are made up of three-dimensional images. They are interactive in real time; they are navigable; and they can be accessed via the Internet. They do not use vision headsets.

The Feeling of Presence. The feeling of being present in a virtual environment is sometimes combined with that of immersion, but it forms the psychological aspect, while the notion of immersion refers rather to the technological aspect. The notion of «*presence is the psychological feeling of being there in the environment, of which immersion is the technological basis*» (Slater and Usoh, 1993). The presence sensation in a virtual environment is sometimes mixed with that of immersion, but actually refers to the psychological side, whereas the notion of immersion refers more to the technological side. The notion of "*presence… is the psychological sensation of being in an environment whose technological base is the immersion*" (Slater and al., 2001). Moreover, the immersive solution system does not necessarily include the presence sensation for the user (Slater and Usoh, 1993, Slater and al., 2001). Indeed, the presence sensation is not characteristic of Virtual Reality and could also be associated

with other media such as cinema, literature, or theater. The presence sensation can therefore appear in a non-immersive environment. In an experimental study, Shubber (1998) demonstrated the existence of a presence sensation during the playing of video games, considered as non-immersive virtual environments. The interactive aspect, user action on the environment and the action of images on their perceptions appear to be sufficient to provoke a presence sensation in the user and "*the perceived image coupled with the action (is) sufficiently strong to make the player react and experience a presence sensation*". The presence sensation therefore seems to be independent of the degree of immersion in the environment. In order to perceive the sensation of being present in an environment of virtual reality rather than in other media, Barfield and Hendrix (1995) distinguished "virtual" presence from presence in the physical environment: "*virtual presence is generally conceived as being a subjective and hypothetical state of consciousness and implication in a non-present environment*" (Barfield and Hendrix, 1995). The term telepresence is sometimes designated by some researchers as being synonymous with the presence sensation: "*telepresence is defined as the experience of presence in a virtual environment…*" (Steuer (1992). For Steuer, the term presence refers to the natural perceptions of an environment whereas telepresence refers to the mediatized perception of an environment. "*This environment can be a non-existent animated virtual environment that is synthesized by a computer (for example, an animated world created in a video game)*" (Steuer, 1992).

Functional Interaction. In virtual environments, the user's interactions are said to be subordinated to four tasks, according to Fuchs et al. (2001), as regards functional interaction.

The user's four tasks are:

- Observe the virtual world
- Navigate in the virtual world
- Act upon the virtual world
- Communicate

We can therefore describe the structure of our experiment as an immersive (technical and psychological immersion with a structure giving the feeling of presence) and interactive structure.

- **Immersive:** our experiment entails a 3D device in the setting of media-based, educational communication. The students were equipped with a HMD and had a 360 degrees vision in the virtual world (with egocentric view of the virtual world). The immersion was technical (with the HMD) and psychological, giving the feeling of presence in the virtual environment (this kind of immersion was tested by a questionnaire of presence of Witmer & Singer 1998).
- **Interactive:** (functional interactivition) because the students could act upon the virtual environment, observe the virtual world, navigate in the virtual world.

Our initial hypothesis was calling upon an increasing number of sensory modes simultaneously makes it possible to increase performance of the long-term explicit memory of the information delivered by the didactic content (Paivio, double coding theory (Paivio and Caspo 1969).

We must now describe the type of memory that we have tested in our experiment and, for that purpose, call on the theories inherent in the memorization processes within the learning programs, notably in the domain of cognitive sciences.

2.2 Cognitive Theories of Memory

Memory Systems. According to Lieury and Clavez (1986), we distinguish:

- **short term** memory from
- **long term memory.** In long term memory, the cognitivist researchers distinguish visual and verbal memory, semantic and episodic memory, implicit and explicit memory, declarative and procedural memory.

Long Term Memory

Visual Memory and Verbal Memory. According to Paivio (1991) and his theory of double coding: the images can give rise at one and the same time to verbal coding and to imaged coding.

1. Hence, information can be recovered via either one of these two codes or via both.
2. The imaged code is always more effective than the verbal code (Paivio and Caspo, 1969).

Semantic Memory and Episodic Memory: Tulving (1972). According to Tulving (1972), we may distinguish:

1. Semantic memory which has to do with the comprehension of speech and the memory of general knowledge that the subject possesses about the world.
2. Episodic memory that refers to the storage of information corresponding to a particular event experienced by the subject. It contains temporal and spatial information that specifies where and when this piece of information was acquired.

Implicit Memory and Explicit Memory

1. Implicit memory shows up in the tasks that do not require conscious or intentional retrieval of information on the subject's part (indirect measurement method).
2. Explicit memory covers the tasks of direct memory (recall and recognition) in which the retrieval of information previously presented is conscious and even prescribed by the task (direct measurement method).

Declarative Memory and Procedural Memory

1. The information stored in declarative memory corresponds to the knowledge of something
2. Procedural information corresponds to knowing how to do something.

As far as our experiment is concerned, we have tested long term / explicit memory. In fact, that is the form of memory at work when memorizing a course, even if learning brings several forms of memory into play.

3 Protocols of the Experiment

Initial Hypothesis. Calling upon an increasing number of sensory modes simultaneously would make it possible to increase the level of the processes implicated in memorizing information delivered by the didactic content (Paivio, 1991).

Experiment. We formed 5 homogeneous groups of students (18 students per group in the 2nd year of initial training, DUT of TC at the IUT of Toulon, in the setting of our courses in the Psycho-sociology of Communications).

The Equipment Used for the Course in 3D. For our experiment, the students were equipped with:

- A HMD (Head Mounted Display, that is, a Sony Glasstron LDI-D100B ruggedized vision headset (LCD screen, Resolution 800x600, non-stereoscopic, visual field 26° Horizontal, 19.6° vertical, headphones with stereophonic sound).
- A Tracker (movement detector) Intersense intertrax² (3 degrees of freedom, angular resolution: 0.02°, latency time 4 ms : internal refresh rate of 256Hz), mouse buttons as navigation tools.
- Software used: Unreal 2004, 3D Studio max, Actor X, PowerPoint.

The Personnel Involved in the Project. Close collaboration with:

- A physician and neuro-psychologist doctor, who has elaborated a system conceived within a virtual environment in order to treat patients suffering from phobias by successive habituation. He conceived the story-board of the course in virtual imagery, the animations and the course in virtual imagery.
- A media engineering student from the University of Toulon and the South, a specialist in synthetic images, has created, in the framework of a proficiency grant, the 3D images for the course in virtual imagery.

Experiment: Report, the Courses

1. An oral, media-based course: the course was dictated, the students did not take notes.
2. A media-based course in PowerPoint alone but without taking notes. The images and the diagrams were the same as those that were used in the course in synthetic images.
3. A media-based course in PowerPoint, with note taking. The images and the diagrams were the same as those that were used in the course in synthetic images.
4. A media-based course in virtual imagery (3D, vision headset, total immersion).
5. A control group course, the pre-test and the post-test only.

Hypotheses

- H1: a course by means of virtual images makes it possible to memorize better compared with other types of media-based presentations (auditory, PowerPoint without notes, PowerPoint with notes);
- H2: the type of media-based presentation acts on the communication of course content and the students experienced the four types of media-based presentation differently.

Approach. Our approach combined:

- a quantitative analysis based on hypothetical-deductive reasoning in order to analyze whether an immersive 3D structure in the framework of our courses on the Psycho-sociology of Organizations can have effects on memorization (with a pre-test and a post-test 3 months later with Anova to compare the results).
- a qualitative analysis a) in order to understand how the students experienced the different communications situations across the four types of med ia-based presentation; and b) to test the sensation of presence in the course presented by means of virtual images (with qualitative interviews).

Methodology H1. A way of verifying hypothesis H1 was to construct a quasi-experimental system that allowed us to vary the different dimensions of the Independent Variable (IV) and to create teaching structures each one of which corresponded to a mode of the IV that we wanted to test, that is, the structure of the media-based presentation.

Data Processing H1

- The IV has several modes: course A auditory, course B PowerPoint without note taking, course C PowerPoint with note taking, course D by means of virtual images in immersive 3D.
- The differences in results obtained by the courses were calculated by variance analysis (Anova), and by a test T. of the Student.

4 Results

Anova Results H1

- Group 3 (PowerPoint with note taking) is the one that had the clearest significant improvement in performance.
- By decreasing order of performance, group 2 came next (PowerPoint without note taking), then group 4 (virtual images with HMD, immersive and interactive course), then group 1 (auditory) and last came group 5 (the control group).

Results of the Qualitative Treatment H2. The recurrent themes in the group 4 (virtual images with HMD, immersive and interactive course) were the following:

- **theme 1: positive aspects of the structure**, examples of sub-themes: playful, interactive, animated, convivial;
- **theme 2: constraining aspects of the structure**, examples of sub-themes: difficulties: technical, physical, pedagogical, communications;
- **theme 3: immersive aspects of the structure**, examples of sub-themes: immersion: physical, real, feeling of presence, feeling of involvement;
- **theme 4: proposals for improvement**, examples of sub-themes: technical improvements, pedagogical improvements, communications improvements ;
- **theme 5: cognition and learning**, examples of sub-themes: memory, attention, learning, comprehension;
- **theme 6: perception of the general course of the Psycho-sociology of organizations**, examples of sub-themes: pleasant memories;
- **theme 7: perception of the experimental course in virtual images**, examples of sub-themes: fantasy, motivating, disappointment.

Results of the Test of Presence H2. The results show that the students had a feeling of presence within the virtual environment of the course in immersive 3D.

5 Discussion and Conclusion

1. Our study showed that in the course in virtual imagery (total immersive device with HMD) the performance of long-term memory is no better than in the other courses. Group 3 (PowerPoint with note taking) is the one that had the clearest significant improvement in performance. And by decreasing order of performance, group 2 came next (PowerPoint without note taking), then group 4 (virtual images), then group 1 (auditory) and last came group 5 (the control group).
2. The results show that the students had a feeling of presence within the virtual environment of the course in immersive 3D. This feeling of presence is physical and psychological.

We assume that the average score of students in the group virtual images could be explained:

1. The cognitive load theory: in fact, students were sometimes embarrassed by the HMD, they experienced headaches or heart, the hardware could cause mental or cognitive overload. Mayer and Anderson (1991), Mayer (1998), Sweller (1994, 1999) take into account in their models the notion of mental activity associated with multimedia learning, Sweller, Ayres, Kalyuga (2011) defined the concept of cognitive load by placing it in the problems of multimedia learning. Cognitive load is defined by these authors as the mental workload that the execution of a task imposes on the cognitive system. Varies depending on the quantity and quality of information presented in a multimedia educational product, the cognitive load is assumed to depend on storage capacity and processing information in working memory learners. The theory of cognitive load may partly explain the poor performance of students in memory if the current 3D immersive virtual images;

2. the effect of habituation may be too long (we had planned to let students get used to the device for a quarter of an hour, but this time perhaps has not been sufficient, also another experiment might be to lead by allowing students to have time to get used the device much longer).

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