IS THREE BETTER THAN TWO? A STUDY ON EEG ACTIVITY AND IMAGINATION ABILITIES IN 2D VS 3D STIMULI

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Abstract – Real and virtual are often considered terms in reciprocal opposition, but the boundaries between the two are blurred. The main goal of our study consists in answering the question whether the presence of a third dimension (3D) is a fundamental step of the virtual toward the real world, and if it causes some difference in the neural activity of the spectator [8]. Also, the possibility to consider real what is virtual will be discussed [6, 7].

INTRODUCTION: AIMS AND MOTIVATION

"Real" and "virtual" are often used as opposed terms but, even if they are still divisible, the boundaries between the two are blurred. The properties of reality that cannot be reproduced by the virtual world are increasingly diminishing, in a path that will lead the virtual to cross the real and, perhaps, to overtake it.

The term "virtual" has been used since ancient ages and derives from the word "virtue": by definition, it is something that could exist but has not yet been realized, but which has the virtue of being realized. Lately, the term was adopted by scholastic philosophy to indicate what exists in power and is able to actualize (for example, the tree is virtually present in the seed). The reference here is to the Aristotelian philosophy, where one of the categories of being, that of change, was related to the passage between potentiality and act [1, 13].

Now, we are witnessing the reverse process: the virtualization of an object as the consequence of a creative process in which a piece of reality is transformed and coded by means of electronic systems. This way, the starting object is still recognizable, but transformed in its natures, being recoded in a secondary format. For instance, a chair placed in front of us, but displayed by a monitor, is no longer made of wood, but of numbers; it has the appearance of something you can sit on, but you cannot interact with, you can only watch it and think about its cognitive and behavioral potentialities [11]. Indeed, to understand the basic principles of how 3D technology works, it was necessary to understand how vision can create the effect of depth that allows us to locate objects in three dimensions. This is attributable to the specific anatomy of vision: in fact, humans have two front eyes with an interpupillary distance of about 65mm. Then, the brain operates on the two different images, to elaborate a coherent and unitary interpretation of what a person is actually seeing.

The history of 3D technology has a remote beginning, still linked to photography. An example was already present at the Great Exhibition of 1851: by using a stereoscope (an invention by D. Brewster), a photo of Queen Victoria was shown in 3D instead of the conventional 2D format of pictures and paintings. Here, something more than a simple perspective effect was presented: it was the real recreation of human vision.

The first film projected was "The Power of Love" that exploited a traditional strategy to create the 3D experience. Indeed, two images were superimposed on the screen, so that they become staggered with a "double" effect. Then, special glasses must be used to divide the images. In fact, the problem is to make the individual eyes perceive only one image as it was in the old stereoscope. At the beginning, this phenomenon was obtained with the glasses, called anaglyphs, with a green and a red lens (then cyan and red for better performance). In fact, they allowed the eye covered by the red lens to see only the projection that was not excluded by the filtering of the colored lens.

Obviously, the notable disadvantage of this technology was the very poor color rendering. At present, the most widespread alternative, thanks to effectiveness and low cost, are polarized light glasses: this technology exploits the polarization of light to separate the image to be sent to the right eye from that meant for the left eye. The lenses are orthogonally meshed (one vertical or one horizontal) and the image is filtered and received independently from the two eyes.

The major flaw of this technology is that the two images are projected simultaneously on the screen and must therefore share the resolution. In other words, the final image will have a resolution equal to half of the projected one. In addition, some subjects experience headaches of varying intensity after a prolonged vision. Finally, it is necessary to keep the head straight; otherwise, the retina of the lenses would no longer coincide with the polarization of the image. Indeed, if the images are not correctly filtered, an annoying "double effect" occurs.

Also, there are active glasses that, through an internal battery, perform the required processes to dissociate the images of the screen. They are called "shutter glasses" because they are based on the same shutter principle of cameras. The lenses of these glasses are composed of liquid crystals that alternately blur at a very high speed (up to 300 times per second); the image projected on the screen is synchronized with the frequency of lenses opening and closing, in order to send a specific signal to each eye.

In any case, the virtual 3D has now "invaded" the space of the real 3D: what we see is no longer limited to that fictitious space that is the monitor or the cinema screen, but moves towards the viewer, thus acquiring a spatial dimension [16]. In fact, when we watch a 3D movie, the effect of depth is not only created towards the "inside" of the screen (like a perspective effect of a Renaissance painting), but some objects extend completely outside the plane to which the screen belongs [2, 3].

This kind of images also become solid in a geometric way. The viewer of this three-dimensional projection has the feeling that the object is within reach. When the visual involvement is optimal, he reacts as if he could touch and interact with the object [4].

A feature of real objects that is lost in their transposition into two dimensions is corporeity, which is the perception of the object observed as an opaque body with its own mass. One thing is to see the 2D image of a stone, another to see that same stone in 3D. In both cases, the object is familiar and therefore we could attribute it an estimate of weight. However, being in front of this object in three dimensions gives us additional information that, with a standard format, we would not have. Certainly, not everyone (neither the spectators, nor the directors) appreciates this increase in information and the related change in perception, perhaps because the main purpose of a movie is not to interact with objects and/or people, but to be captured by a story in a fantastic world.

OBSERVATION AND BRAIN ACTIVATION

The observation of an action performed by others triggers in the observer the same neural networks, as if we were in the first person to carry out the action. This evidence paved the way for the idea that action observation could be used as an effective way to learn or improve the performance of a specific motor skill. A particular type of "observation" was already successfully applied in the world of sport and rehabilitation. In fact, by using motor imagination, it is possible to visualize the movements and involve the motor areas that will then be activated during the execution of the same movement [9, 12].

However, this requires a high level of concentration on the body part of the subject. The person must imagine himself performing specific actions and therefore its application could be difficult, especially when the motor imagination is applied for clinical purposes. In fact, it is not always possible to ask patients, often in suffering conditions, to carry out this concentration effort. It is also impossible for therapists to verify if the subject is visualizing the movements in the correct way and accompanying them in the rehabilitation process. The observation of actions seems a simpler and more easily applicable method.

A recent study by Gatti and colleagues [10] highlighted how action observation treatment (AOT) is more effective than motor imagery when it comes to learn a complex motor task. The study focused on the learning phase of the movement and, although the neural structures involved were the same, it is believed that the visuo-motor system is activated in a deeper way when observing the action. In fact, the ventral premotor cortex receives visual inputs and it is stimulated by a visual signal rather than by the will to visualize movement while it is not present.

In addition, during action observation, the subject has a model that performs the action correctly. Conversely, motor imagination must rely only on his ability to recall exactly the relevant motor representation and to mentally develop the movement correctly [5]. The results of the study also showed greater accuracy in the execution of the movement by the subjects who had followed the AOT program.

In the present study, we aimed at answering the following questions: Is the use of three-dimensionality in video a fundamental step of the virtual towards the real? Does this lead to some difference in the level of cortical and peripheral activation of a spectator? Moreover, some possible applications of AOT in clinical practice are desirable [15].

THE EXPERIMENT: MATERIALS AND METHODS

Participants

Twenty man between 20 and 60 years-old participated in the experiment (M=32.6 years). All participants were right-handed with normal or corrected-to-normal visual acuity. Exclusion criteria were: left-handedness, the presence of any neurological disorder or cognitive impairment, visual disorders, a previous surgery at the left knee or pre-existing motor impediments (such as hemiparesis, lumbar sciatica). No payment was provided for subjects' performance and they gave informed written consent to participate in the study.

Stimuli and procedure

After taking place on a comfortable chair in a dimly lit room, two videos, identical in their contents, were proposed to participants, both in 2D and 3D presentation. Videos comprised a target condition, in which leg movements were displayed, together with two control conditions, in which arm movements or naturalistic neutral scenes (N) were proposed. In detail, the extension movement of the left leg (L) and the flexion movement of the left arm (A) performed by a male actor were used. Each different content was presented four times, in a randomized order. The video cuts lasted one minute, and were assembled in randomized sequences, for a total of 12 minutes for each modality (2D vs. 3D): four minutes of G, four minutes of B, and four minutes for N. The order of vision of 2D and 3D movies was also random (see Fig. 1). The videos have been filmed with constant artificial light (280 lux). During the experimental phase, changes in the muscular tone (electromyography, EMG) and in the cortical activity (EEG) were measured.

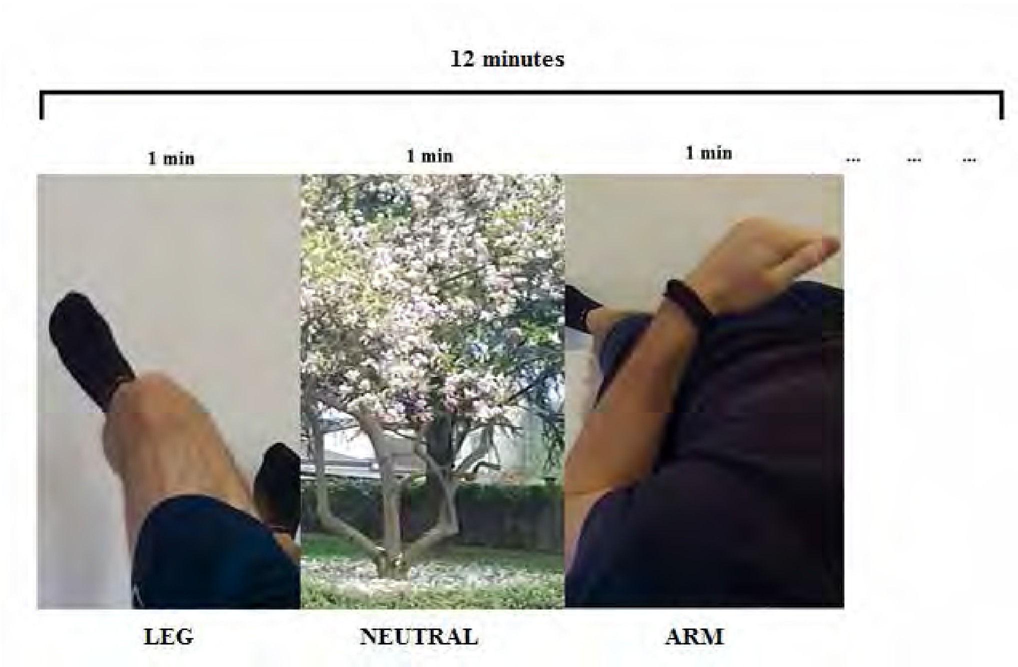

Fig. 1: Display of stimuli presentation with Leg (L), Arm (A), and Neutral (N) conditions presented in a randomized order.

EEG recording

EEG signal was acquired by using a MindCap XL Headband (Neurosky). The tool consists of an elastic band with due electrodes: the active one was positioned over Fp1, and the reference electrode over Fp2. Also, a clip to be attached on the left earlobe was present. The system was battery powered and the signals were sent via Bluetooth to a computer that recorded them through the NeuroView software. The sampling frequency was 512 Hz for the filtered signal and 7 Hz for the Power Spectrum reporting the frequency of all brain waves with a range of 4 Hz (Delta 0-4 Hz, Theta 4-8 Hz, Alpha 8- 12 Hz, Beta 18-22 Hz, GammaLow 28-32 Hz, GammaHigh 38-42 Hz) (see Fig. 2).

Fig. 2: MindCap XL Headband positioned over Fp1.

EMG recording

Muscular activation involves the action of muscles and nerves, which is triggered by very small electrical currents. Measuring the electrical activity in muscles and nerves can be useful for Human-Computer Interaction, control, biofeedback and many other applications. The sensor is capable of performing electromyography (EMG) measurements using bipolar surface electrodes (plus a ground lead), and monitors the muscle activation.

EMG signal was acquired by using BITalino (Plux Wireless BioSignals SA) and OpenSignals as acquisition software. BITalino is wireless bluetooth device that can collect different biosignals. The EMG signal was collected with a sampling rate was 250.

RESULTS

The power of each EEG band was submitted to different repeated-measures ANOVAs with video content (3 levels: L, A, and N) and modality (2 levels: 2D, 3D) as repeated factors. A significant Content effect has been found with respect to Alpha waves ($F_{1,2}=6.04$; $p<0.01$). Post-hoc comparisons showed that Alpha levels during the observation of leg movements were significantly lower compared to arm motion videos and neutral natural scenes. No significant differences were found between arm and neutral scenes (Fig. 3).

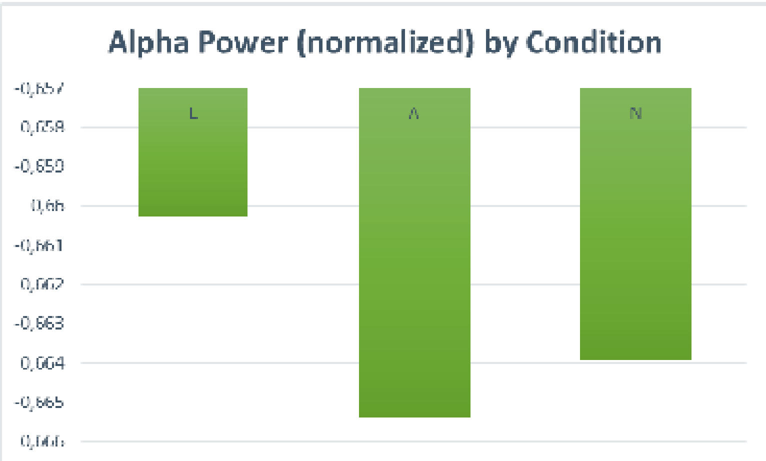

Fig. 3: Alpha Power (normalized values) while viewing Leg (left), Arm (centre), and Neutral (right) movies.

No significant differences were found with respect to the projection mode (2D and 3D) even if constant trends were found: during 3D projections higher power values were recorded, than those found in the 2D video. Moreover, no significant differences were found for peripheral measures.

DISCUSSION AND CONCLUSION

The present work aimed at exploring the brain and peripheral correlates during the vision of 2D vs. 3D scenarios depicting specific body movements with rehabilitative purposes.

A significant result was found for video content in the alpha range, with lower values during observation than arm and neutral. Alpha waves are typically linked to the functioning of the medial cortex. The areas that lie between the prefrontal areas up to the parietal lobe constitute the so-called "default system", and are intended to manage the cognitive system in the absence of a particular high level engagement. Thus, when a subject is engaged in a task that is not particularly challenging, these areas become dominant and lower the frequency of the areas that are not involved in the current task. On the other hand, when there is a relevant cognitive task, this default system loses its synchronization value and the various structures related to the task raise. This interpretation is supported by a study conducted by Mo and colleagues [14] in which the activity of Alpha waves was recorded for short intermittent periods with eyes closed and open showing how, on average, the intensity of the oscillations of Alpha (8-12 Hz) decrease in the tasks in which attention is focused on the outside, as could be the observation of images.

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