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Brain activity during virtual and real dart throwing tasks in patients with stroke: a pilot study

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Abstract. Stroke is a neurological problem that may cause severe sensorimotor impairments. Motor recovery is an important goal for neurorehabilitation. Virtual Reality (VR) provides positive and dynamic individual-task interaction. Nevertheless, the use of VR as an intervention technique in rehabilitation raises the question about the similarity of sensory-motor perception between real and virtual environments. This similarity between real and virtual environments could be explored in neurorehabilitation. This research compared brain activity and arm movement during virtual and real dart throwing tasks between stroke patients and healthy subjects. The participants included two stroke patients and two healthy individuals. During evaluation participants performed 15 trials during a real dart throwing task, and 15 trials during a virtual dart throwing task. Stroke patients performed the tasks with the paretic upper limb. The brain activity was captured with an Emotiv EPOC® system (portable EEG system with 14 sensors + 2 references). The brain activity data was supported on power spectral analysis of Beta waves at 22 Hz, and Gamma waves at 40Hz. Data revealed similarities on brain activity between virtual and real dart game tasks, with activation of the primary motor cortex in the right cerebral hemisphere (FC6), for both stroke and healthy participants.

Keywords: Stroke, Dart throwing, virtual reality, Brain activity, Rehabilitation

1. Introduction

Stroke is a neurological problem that causes severe sensorimotor, cognitive and functional impairments. Motor recovery of upper limb dysfunction is an important goal in rehabilitation depending on the functional reorganization of the Central Nervous System (CNS) [Patten et al. 2013].

Virtual Reality (VR) is considered a promising tool for functional Neurorehabilitation, providing intensive repetition of complex tasks, positive and dynamic individual-task interaction, and may also remove limiting factors related with physical constraints [Wright, 2014]. Previous studies using virtual reality in motor rehabilitation aim to rate VR consoles efficiency and effectiveness [Cameirão et al. 2012]. The use of VR as an intervention technique in rehabilitation raises the question about the similarity of sensory-motor perception between real and virtual environments [Wallet et al. 2009].

The literature considers that the level of accuracy of a motor task performed in different environments can be assessed by brain activity analysis, and/or movement kinematic analysis [Cheng et al, 2015; Tamai et al. 2011]. The adaptive information processing in motor execution is associated with a decreased activation in the sensorimotor cortex. Skillful performers like golfers or pianists, when compared with novices, are considered to execute motor actions with lower activation in the sensorimotor cortex, lower conscious processing, or less cognitive involvement [Babiloni et al. 2008; Meister et al. 2005; Milton, et al. 2007]. This decreased monitoring control of motor performance is usually associated with an augmented sub-cortical control, which means less conscious and more automatic. This type of studies point out to either structural or functional modifications in the motor cortex activity after long-term practice experience [Dayan & Cohen, 2011; Gruzelier et al, 2010].

Due to the movement similarity between real and virtual environments (e.g., videogame tasks), it was hypothesized that the usage of virtual environments during physiotherapeutic practice sessions could be useful in neurorehabilitation.

This research aimed to compare the brain activity related with arm movement during virtual and real dart throwing tasks of stroke patients and healthy subjects.

2. Material and Methods

2.1. Sample

The participants, all dexterous, included two patients (one with right brain injury and the other with left brain injury, aged 41 and 69 years) and two healthy subjects (aged 38 and 60 years).

The stroke patients were evaluated through the National Institute Health Stroke Scale (NIHSS) presenting a neurologic impairment of "mild". The motor evaluation was performed by the Fugl-Meyer Scale using the upper limb subsection, which specifically evaluates the reflex activity, isolated movements and synergistic patterns, hand activities, as well as motor coordination and speed of movement. Stroke participants presented a motor impairment of "mild to moderate".

All participants provided their informed consent and were approved by the ethical committee of the UFRN. Subjects were informed that they had the right to withdraw from the study at any time, and were asked to refrain from having drinks containing alcohol or caffeine at least 24h prior to their arrival at the laboratory.

2.2. Measurements and data analysis

During evaluation all participants had to perform 15 trials during a real dart throwing task and 15 trials during a virtual dart throwing task, using the Kinect Sports game and the Xbox 360º Kinect console (see Fig.1). In the real condition the distance from the dartboard to the throwing line was 2.27 meters, and the distance from the floor to the center of the bull's-eye was 1.74 meters (consistent with the international dart rules). The dart-throwing task consisted of 15 self-paced dart throwing trials divided in 3 separate recording blocks of 5 trials with a 5 minute rest period between each block, for each condition, in order to avoid fatigue. Participants were asked to start when ready and were instructed to throw as accurately as possible. They were asked, firstly to hold the dart in front of the chest for 2 seconds and use their wrist and elbow for aiming and shooting, with minimum body sway.

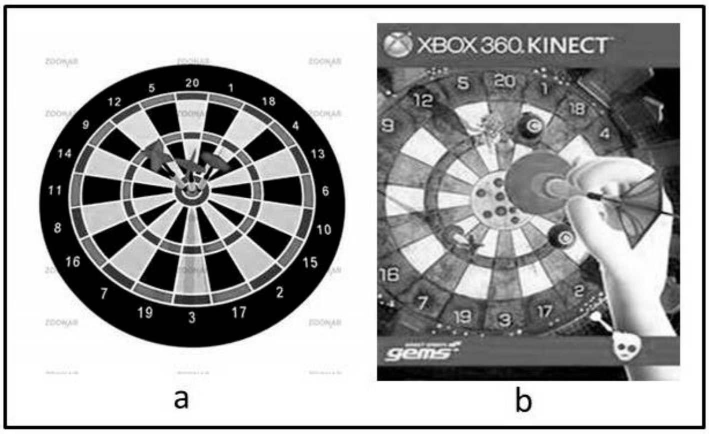

Figure 1. *Experimental conditions: real (a) and virtual (b) dart throwing conditions.*

The two participants with stroke performed the tasks with the paretic upper limb (right and left limb, respectively), one of the healthy participants performed with the right limb and the other with the left limb.

The brain activity, registered for each block of 5 trials, was captured with an EMOTIV Epoc - 14 Channel Wireless EEG Headset fitted to the participants to record their EEG signals from 14 scalp electrodes (AF3, AF4, F3, F4, FC5, FC6, F7, F8, T7, T8, P7, P8, O1, O2) + 2 references (Left/Right Mastoid Process / Alt P3-P4), based on the international 10-20 system (see Fig. 2). Data were collected with a frequency of 128 samples per second, per channel.

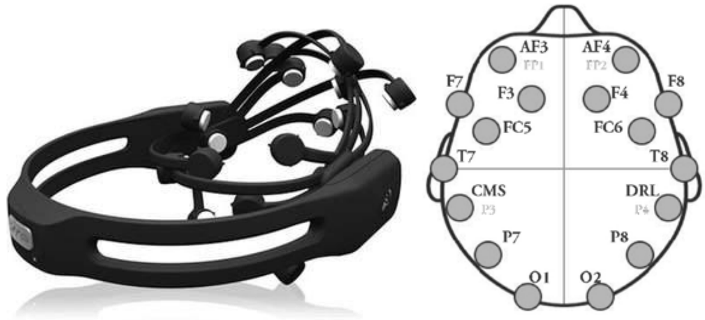

Figure 2. *Emotiv Epoc System, and electrode localization.*

The artefacts, defined by amplitudes exceeding 100 µV from baseline were removed through visual inspection by the experimenter. After that, data were high and low pass filtered at 1 Hz and 50 Hz respectively. Brain mapping for each block of 5 trials was generated using an independent component analysis process.

Brain activity data concerned power spectral analysis of Beta waves (22 Hz), associated with attention and interaction with the environment, and Gamma waves (40Hz), associated with information processing from different brain areas.

The intensity of the brain waves on the scalp was analyzed through the color graduation, in which red color represents higher activation (dark area) and dark blue represents few or no activation (light grey area). The kinematic analysis of elbow movement amplitude was assessed using a Qualisys Motion Capture System, composed of 8 video cameras, a group of infrared reflectors, and a group of body reflectors placed on the arm joints (19 mm spherical passive markers). Due to the reduced number of participants we didn't perform any statistics analysis.

3. Results

Data concerning only the last block of 5 trials, revealed similarities on brain activity between virtual and real dart game tasks, with activation of the primary motor cortex in the right cerebral hemisphere (FC6), for both stroke and healthy participants (see Fig. 3).

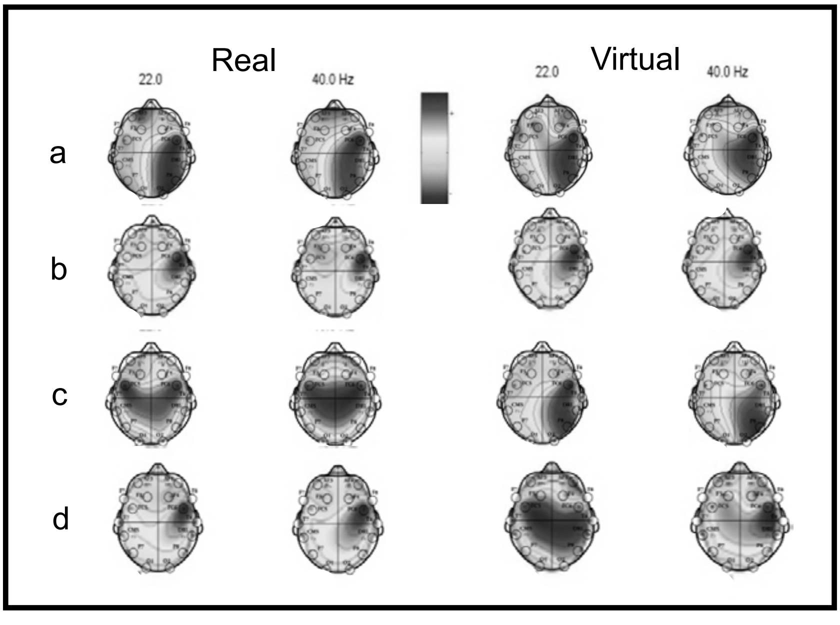

Figure 3. *Brain activity during real and virtual dart throwing (a – patient with right hemisphere injured, left hand throw; b - patient with left hemisphere injured, right hand throw; c - Healthy, left hand throw; d – Healthy, right hand throw).*

Performing in the virtual environment activated more areas of multisensory integration (parietal, temporal and occipital cortices). Results indicate prevalence in the activation of the primary motor cortex and the parietal cortex, including the somatosensory and visual-spatial processing areas, which might have revealed the sensory-perceptual-motor demands of the virtual practice.

4. Discussion

Neuroscience research highlights that the right brain hemisphere can be dominant with spatial attention and perception demands [Dietz et al. 2014].

Our data corroborate the results from previous research, by displaying that, independently of the laterality of the arm used to perform and the injured hemisphere, the right hemisphere was the most activated in the course of action for both performance environments.

By stimulating the right brain hemisphere in both practice conditions (i.e., real and virtual) our results sustain the use of virtual game tasks for motor rehabilitation of stroke patients [Lisa et al 2013]. The virtual and real dart game tasks also differ in the kinematic parameters. Results revealed a wider angle of the elbow extension while performing the real game task. These data can be associated with task constraints as weight, size and thickness of the dart which requires a larger arm movement in order to throw the dart in the most accurate flight path towards the target. On the contrary for the virtual game task, due to the absence of the dart, this wider arm movement is not required. Another important issue is that a smaller range of motion of the elbow in the virtual game task can also be beneficial for patients with elbow extension restrictions due to moderate or severe spasticity, or joint stiffness [Fernandes et al. 2014]. On the other hand, the real game task which requires a wider angle of the elbow may be indicated when the aim of the rehabilitation is an increase on motion amplitude of this joint. The results allow us to infer that the virtual and the real environments may offer different advantages for Neurorehabilitation inducing different behaviors.

5. Conclusions

The practice of a virtual dart throwing task did not differ significantly from the real one in what concerns brain activity. In both conditions the right brain hemisphere was the most activated one, as a result of the main characteristics of the task, demanding attention and spatial perception. Movement kinetics during virtual task performance is not impeditive for satisfactory game results inducing motivation and desire to continue practicing.

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