Volume 19, Year 2021
ISSN: 1554-8716

Annual Review of CyberTherapy and Telemedicine

Virtual Reality Therapy in the Metaverse: Merging VR for the Outside with VR for the Inside

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http://www.arctt.info

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ISSN: 1554-8716

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Annual Review of CyberTherapy and Telemedicine

 Interactive Media Institute
6540 Lusk Boulevard, Suite C115
San Diego, CA 92121

ISBN: 1554-8716

Printed in the United States of America

Journal Website: http://www.arctt.info
Interactive Media Institute Website: http://www.interactivemediainstitute.com

Section VI. Work In Progress

The immersive 3D objects' library for applying non-invasive brain stimulation in research on the motor control and the mirror neurons system: a call for collaboration[1]

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Abstract. We have developed and tested a library of 3D objects for the study of motor control in immersive reality (https://p3d.in/TK7k3). The use of this stimulus material (e.g., as on the Figure 4a) opens up new opportunities for evaluating physiological parameters when using the method of neurotherapy in virtual reality. In combination with the Non-Invasive Brain Stimulation (NIBS) methods such as Transcranial Magnetic Stimulation (TMS), we propose to explore the effects of functional activity of the mirror neuron system on a large scale for further approbation of advanced and promising neurorehabilitation protocols.

Keywords. 3D, Mirror Neurons System (MNS), Non-Invasive Brain Stimulation (NIBS), Immersive Reality for Neurorehabilitation

1. Introduction

The study of the motor control in immersive reality [environments] allows us to identify physiological differences between traditional approaches of neurotherapy (for example, mirror therapy after a stroke) and "non-traditional" using virtual reality (VR) coupled with TMS for the functional effect(s) of the mirror neuron system (MNS). Also, the activation of the human MNS can be a good objective criterion for more widely practical application in rehabilitation programs.

2. The research of the MNS system with NIBS

The classic approach to the investigation of MNS involves single pulse TMS application over the motor cortex in order to elicit motor evoked potentials (MEPs) from the contralateral (to the site of stimulation) arm muscles in human volunteers. This requires the subject to observe an experimenter grasping objects, so called "transitive hand actions", or performing meaningless arm gestures – "intransitive arm movements".

[1] Acknowledgement: the researchers used facilities of the HSE unique equipment (Reg. №354937) supported by the RF Government grant (ag. №075-15-2021-673), partially it was supported (granted) by DeMontroyal.
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Evidence (of Fadiga et al., 1995 [1]) has shown that the observation of both transitive and intransitive actions determined an increase of the recorded MEPs [2]. Therefore, we have developed 3D hands in open-source 3DCG software toolset Blender version 2.92.01

(Blender Foundation, Netherlands) which were sketched from a scratch, modeled and mashed, and integrated in a simple environment (a light table with a white ball and grey-colored interior). The grasping movement is animated to the hand as well. Additionally, we have created 2 to 4-second video clips involving the hands' movement (you can see 2D shots from clips on Figures 1a, 1b, 1c, 2a, 2b, and 2c). A hand-made hand is an (virtual) asset. It may be exported and used in the process of developing an experimental design on a virtual platform (e.g., on cross-platform game engine Unity).

2.1. Action observation and the MNS

The mirror neurons are not reacting to the mere observation of a movement (purely motoric), but their activity is also related to the intention of the action execution. This account identifies a precise role for the MNS in our ability to infer intentions from other people's actions [3]. Here, we have developed the stimuli for NIBS testing in a VR-contained hand grasping a ball (the movement from the front view point, 0°: Figures 1a-1c, and the movement from the opposite view point, -180°: Figures 3a-3c). So, we had prepared and adopted those stimuli for testing subjects in the project studying the effects of MNS. Interestingly, by animating the 3D hand and customizing movements as a constructor (see library: [4]), the researcher might play with them or create a design of his/her study in an easy way. Importantly, any design will be standardized and circulated (lab2lab) ecologically.

2.2. Study of the empathy for pain, racial bias, and the MNS

Evidence showed a reduction in amplitude of MEPs which is specific to the muscle of a hand being pricked during observation [5]. The empathic behavior may be based on 'mirror-matching' simulation of others' states. Its inference about the sensory qualities of others' pain and their automatic embodiment in the observer's motor system may be crucial for the social learning of reactions to pain [5]. For testing the empathy for pain, we have developed (other) models of damaged hands (Figure 4a).

Additionally, it has been shown that observation of empathy for pain-related stimuli from black and white humans elicits an implicit racial bias [6]. The research found that observing pain in the same racial group induced a reduction in corticospinal excitability that is specific to the muscle (specific location of the observed hand) which participants observed being affected. For testing the racial bias of the MNS, we have created an additional model of a hand with black skin (Figure 4b) wherein we switch the model of the hand and use it for the same grasping movements (presented in Figures 1a-1c) according to different race groups (i.e., African-American and Caucasian).

Figure 1a. Grasping a ball (1st frame of movement). **Figure 1b.** Grasping a ball (2nd). **Figure 1c.** Grasping a ball (3rd). CC BY-NC-ND [4]

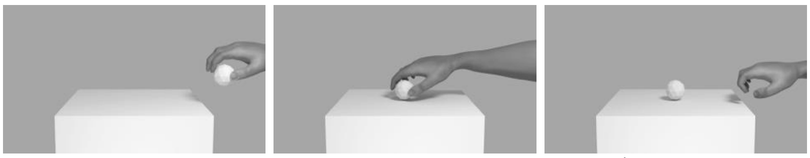

Fig. 2a. Backing a ball (1st frame of movement). **Figure 2b.** Backing a ball (2nd). **Figure 2c.** Backing a ball (3rd). CC BY-NC-ND [4]

[1] https://www.blender.org/

Figure 3a. Grasping a ball: opposite view (1st frame of movement). **Figure 3b.** Grasping a ball: opposite view (2nd). **Figure 3c.** Grasping a ball: opposite view (3rd). CC BY-NC-ND [4]

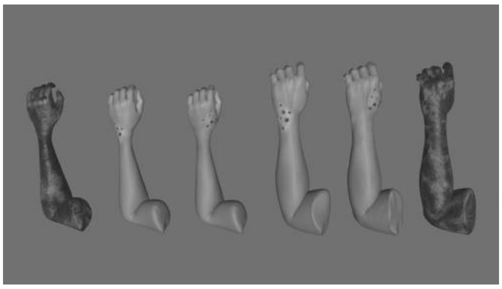

Figure 4a. Damaged hands. CC BY-NC-ND [4]

Figure 4b. Hands with white skin and hands with black skin. CC BY-NC-ND [4]

3. The advanced research with NIBS in immersive reality: a call for collaboration

We have developed a set of 3D objects and examples of standard movements (e.g., Figures 1a-1c; for deep exploring go to: [4]) for its application in neuroscience research. It is by applying this library in collaborative work that an immersive and unified stimuli approach could be tested and implemented widely. 3D virtual stimuli can be useful in advanced study of neurotherapy and personalized remote neurorehabilitation. We propose to scientific groups with a specialty in (human) motor control to discuss and share ideas about mirror therapy and VR in order to create novel neurophysiological projects. We expect that the mirror neurons' effect measured using TMS-induced MEPs can be a predictor of the effectiveness of the therapy. For example, by using a training MNS' protocol in assisted VR, measured MEP index will allow for determining and specifying an optimal approach to the use of therapy, including in VR.

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