Insights from 10 years of stroke virtual rehabilitation – a personal perspective

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During the last decade, the use of virtual reality (VR) for the rehabilitation of motor and cognitive deficits after stroke has became increasingly popular. This trend can be appreciated by the exponential growth over the years of the number of publications that evaluate, propose or review novel stroke rehabilitation and/or assessment paradigms based on the use of VR based technology. In 2006, we started the development of the Rehabilitation Gaming System (RGS), a pioneer VR based system in multiple aspects at that time. Besides some technical innovations – such as a non-invasive low-cost webcam-based motion capture system years before MS Kinect was developed – RGS had very specific mechanistic neuroscientific hypothesis on how VR could be further exploited to maximize stroke recovery. RGS exploited the embodiment of virtual agents, the effect of first-person perspective and Mirror Neuron activation as mechanisms for potentiating neuroreorganization. In addition, RGS was one of the first pushing forward the concept of a build-in adaptability engine to maximize training outcomes through an automated difficulty adjustment that individualized training parameters to patients (Cameirão, Badia, Oller, & Verschure, 2010). The impact of this system in comparison to standard rehabilitation was evaluated by a number longitudinal studies. In the most ambitious and demanding study that I ran, RGS was used in a 3-month intervention (plus 3 months follow-up) in acute stroke patients (Cameirão, Bermúdez i Badia, Duarte, & Verschure, 2011). The results of this study showed that VR based rehabilitation can have an acceleration effect in stroke recovery in the acute phase of stroke. Still nowadays there are not many studies of this kind because the implementation of such a protocol is very challenging and demanding. Nevertheless, controlled studies of this kind were (and are still) needed, and to date this is still one of my most important contributions to the field of virtual rehabilitation. In a later study with RGS, we compared the effect of using 3 different interface technologies (natural user interface, passive exoskeleton, and haptics) with 44 chronic stroke survivors on the same VR task (Cameirão, i Badia, Duarte, Frisoli, & Verschure, 2012). Results showed that the main contributor for the positive results were the VR scenario irrespective of interface technology. Further, retention of improvements on follow up was higher when a haptics interface was used, allegedly because of increased ecological validity in the interaction with the VR scenario.

More recently, I have been particularly interested in the context and content of rehabilitation tasks. One important aspect relates to how rehabilitation is delivered, and different features can be associated to approaches such as coaching or gaming (Cameirão, Smailagic, Miao, & Siewiorek, 2016). Additionally, it became apparent that VR motor rehabilitation approaches were not thoroughly considering all cognitive aspects of motor tasks. There is an increasing body of literature that advocates for a dual motor-cognitive training instead of the rehabilitation motor and cognitive skills separately. Hence, we started studying multiple aspects of integrative motor-cognitive VR rehabilitation. These range from the quantification of cognitive-motor interference based on patient profile or interface technology, use of computational modeling for task personalization, to the recreation of Activities of Daily Living (ADL) in more ecologically valid scenarios.

One interesting line of research is the study of the effect of using emotional content in a cognitive-motor VR rehabilitation task. It is known that emotional stimuli enhance attentional processes, and that such stimuli are recalled differently depending on their valence (neutral, positive, negative). Hence, we wanted to investigate how such premises could be integrated in a VR task for stroke cognitive rehabilitation, and understand what type of stimuli could be more adequate for attention and memory training. For this purpose, we ran a pilot eye-tracking study in which stroke survivors performed a virtual memory-attention task consisting on finding target images of different valence in a pool of distractors (Cameirão, Faria, Paulino, Alves, & Bermúdez i Badia, 2016). We analyzed how performance in the VR task, recall and eye gaze were modulated by the valence of the images. Our results indicate that stroke survivors are less attentive, present reduced visual search patterns and more false memories when negative stimuli are used in the VR task. These preliminary results emphasize the need of a careful consideration of the type of content being used in virtual scenarios as it impacts rehabilitation outcomes. Currently, we are conducting a controlled feasibility study with a similar cognitive-motor virtual reality task exploiting the use of positive stimuli based on the individual preferences of each user. We aim to evaluate the potential benefits of such a protocol in comparison to standard rehabilitation.

KEY PUBLICATIONS

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