A Portable Immersive Virtual Reality Platform for Motor-Imagery Guided Rehabilitation of Hemiparetic Stroke

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Abstract. Stroke is a devestating illness that can have a profound impact on productivity, mobility and quality of life. Current practices for stroke rehabilitation rely on complex robotic actuation devices or a trained therapist to actuate a patient's paralyzed limbs during the imagined or attempted actuation of the paretic muscles. Here we propose a low cost, immersive virtual reality (VR) platform for the rehabilitation of upper extremity deficits that are caused by stroke. Four hemiparetic patients suffering from basal ganglia stroke were introduced to the platform and trained to control a brain-computer interface in conjunction with the standard 1-dimensional cursor task. Patients achieved classification accuracies as high as 77.5% using this VR platform, and grouped average performances were comparable to those achieved using the traditional BCI cursor task.

Keywords: EEG, Motor Imagery, Basal Ganglia, Stroke, Virtual Reality, Anaglyph, Rehabilitation

1. Introduction

The rehabilitation of stroke depends on a patient's early mobilization and the use of the deficit extremity. Mental practice using the deficit limb, in conjunction with actuation by a physical therapist plays an important role in reestablishing damaged pathways and recovering function. Mental practice without adequate feedback is difficult and brain-computer interfaces may offer a novel solution [He et al., 2013; Silvoni el al., 2011; Ang et al., 2011]. Here we propose a novel system for providing realistic, 3-dimensional visual feedback to promote accurate mental practice using a sensorimotor rhythm based brain-computer interface.

2. Materials and Methods

Four subjects with histories of basal ganglia stroke and unilateral limb paresis were trained in SMR BCI control using virtual reality (VR) and traditional 1D cursor feedback (BCI2000). Subjects attended up to three training sessions, each consisting of 10 3-minute trials. In the VR task, the subjects placed their arms inside the front of a box, and viewed a 3D anaglyph video of real human arms from the top of the box such that as they looked "through" the top of the box it was as though they could see their own arms. The video's position was controlled by the position of the 1D traditional cursor, running in the background. Moving the cursor to the left and right extended the left and right arms respectively. Auditory cues signaled the target direction in both tasks.

3. Results

Overall, the group weighted average percent accuracy was 64.0% in the cursor task compared to 65.6% in the VR task. Subject 1 scored 80.5% on average in the standard cursor task and 69.2% in the Virtual Reality task. Subject 2 scored 46.5% in the cursor task compared to 58.4% in the VR task. Subject 3 demonstrated nearly identical performance accuracies in both the cursor task and VR task, performing 54.2% and 54.1%, respectively. Subject 4 demonstrated an average accuracy of 87.4% in the cursor task compared to 77.5% in the VR task.

We additionally tested the expectation that our patient population may operate the sensorimotor-based brain-computer interface in a deficit dependent manner, having lost connection and feedback from the affected limb for a prolonged period. Fig. 1 demonstrates that accuracy was not substantially different between targets presented on the patients' deficit and non-deficit sides. This is an interesting finding that implies that a lack of meaningful feedback from the affected limb does not substantially limit the utility of the healthy cortex in basal ganglia stroke patients for BCI applications.

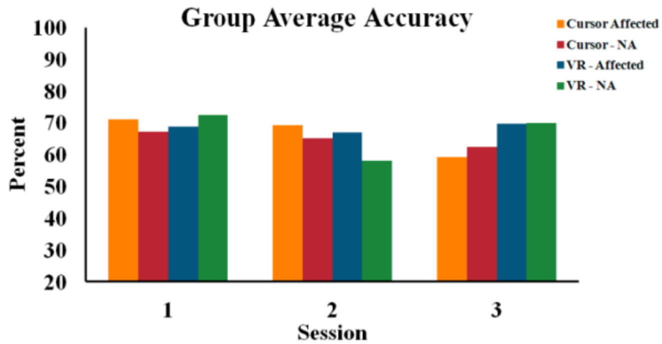

Figure 1. *Grouped percent accuracies by VR vs traditional cursor control task and affected vs nondeficit (NA) side.*

4. Discussion

The system provides a cost effective option for presenting 3D video of arms in alignment with the subject's real arms, together producing a powerful illusion of embodiment. All subjects reported that they could easily imagine the presented arms being their own arms when using this immersive 3D system. For elderly stroke patients, the complex instructions related to BCI and the concept of motor imagery can be difficult to understand. Many quickly abandoned more abstract motor imagery in favor of mentally reaching out to grab the 3D cups. Using this system, patients have the potential for targeted rehabilitation and mental practice with relevant feedback before movement of the deficit limb is possible. The system retains the level of feedback that is necessary for BCI control by hemiparetic stroke patients while providing crucial visual cues.

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