 DOI:10.3217/978-3-85125-378-8-45

3D visualization modalities can have effects on motor cortex activation

Teresa Sollfrank[1*], Daniel Hart[2], Rachel Goodsell[3], Jonathan Foster[3], Andrea Kübler[1] and Tele Tan[2 †]
[1] University of Würzburg, Würzburg, Germany
[2]Department of Mechanical Engineering, Curtin University, Perth, Western Australia
[3]School of Psychology and Speech Pathology, Curtin University, Perth, Western Australia & Neurosciences Unit, Health Department of WA
Teresa.sollfrank@uni-wuerzburg.de, T.tan@curtin.edu.au

Abstract

When pathways for normal motor function are interrupted (e.g. after stroke), brain-computer interfaces (BCI) can be used i) as an alternative channel for communication by translating brain signals measured with electroencephalography (EEG) into a computer output (Kübler et al., 2005) or ii) for rehabilitation by influencing brain plasticity processes to induce recovery of motor control (Pichiorri et al., 2011). This study investigated if a realistic visualization of an upper limb movement can amplify motor related potentials during motor imagery (MI). We hypothesized that a 3D sensory richer visualization might be more effective during instrumental conditioning, resulting in more pronounced event related desynchronisation (ERD) of the mu band (10-12Hz) over the sensorimotor cortices and can therefore improve sensorimotor rhythm-based based BCI protocols for motor rehabilitation.

1 Introduction

Over the past years advances in the analysis of EEG signals and improved computing capabilities have enabled people with severe motor disabilities to use their brain activity for communication and control of objects in their environment, thereby bypassing their impaired neuromuscular system (Kübler et al., 2001; Allison et al., 2007). A new potential BCI therapeutic approach is generating substantial interest in the use of EEG-based BCI protocols to improve volitional motor control, that has been impaired by trauma or disease: A repetitive movement practice e.g., with non-invasive sensorimotor rhythm-based (SMR) BCIs should lead to an increase in the motor cortical excitability (Pichiorri et al., 2011). By inducing a better engagement of motor areas with respect to motor imagery, BCI protocols might be able to guide the neuroplasticity to promote recovery in the affacted brain regions to restore motor function (Cincotti et al., 2012).

Since BCI systems use immediate, typically visual feedback of performance, the influence of the visual feedback presentation should be considered. For instance, there seems to be no difference in the classification results between groups provided with 'realistic feedback' (moving hand performing an object-related grasp) and an "abstract feedback" (moving bar; Neuper et al., 2009) in a SMR based-BCI task. However there is some evidence that instead a rich visual representation of the feedback

[*] Masterminded EasyChair and created the first stable version of this document
[†] Created the first draft of this document

 DOI:10.3217/978-3-85125-378-8-45

signal, e.g., in the form of a three dimensional video game or virtual reality environment, may enhance the user`s control of a SMR based-BCI (Pineda et al., 2003; Pfurtscheller et al., 2006).

This study investigated if a 3-dimensional visualization of upper limb movement can amplify motor cortex activation during motor imagery (MI) and thereby support the use of a sensorimotor rhythm based BCI. We hypothesize that this "realistic" sensory richer visualization might be more effective during instrumental conditioning, resulting in more pronounced event related desynchronisation of the mu band (10-12Hz) over the sensorimotor cortices.

2 Methods

Fifteen healthy SMR BCI naïve participants were recruited for the study. In a within subject design all participants were instructed to watch attentively randomized videos of three different left and right upper limb movements (Fig. 1) on a True3Di monitor in 2D and in 3D visualization, by using stereoscopic glasses. Every session consisted of 3 runs with 12 trials each (3 different movements for the left and right upper limb in randomized order consecutively in 2D and 3D). After every video, participants were instructed to replicate subsequently the observed movements by motor imagery, while the EEG signals were recorded from a grid of 40 Ag/AgCl scalp electrodes. For statistical analyses, we used the ERD values obtained from the right (recording position CP4) versus left sensorimotor cortex (recording position CP3), temporally aggregated over imagery period (1-5 s). The probability of a Type I error was maintained at 0.05

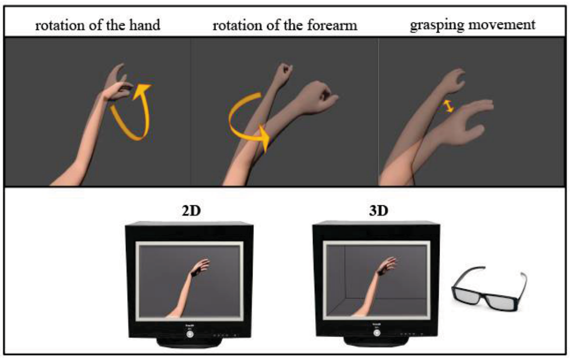

Figure 1: Visualization of three different upper limb movements: rotation of the hand around wrist, rotation of the whole forearm around elbow and a grasping movement of the whole arm. All movements were shown for the left and right upper limb randomized in 2D and 3D.

3 Results

Fig. 2 presents the topographical analyses of the mean ERD values for the two visualization modality groups, separately for the respective task (right and left hand, arm and grasp motor imagery) and electrode position (CP3 and CP4). Characteristic patterns of ERD of mu band components for left and right upper limb motor imagery were present mainly contralateral at electrode positions CP3 and CP4 over the sensorimotor areas. In order to analyze the potential influence of the visualization modality on the ERD patterns during task performance, we performed a repeated measures ANOVA on the ERD data using the Visualization Modality (VM, 2 levels: 2D vs. 3D), Electrode Position (2

 DOI:10.3217/978-3-85125-378-8-45

levels: CP3 vs. CP4), Task (3 levels: arm rotation, hand rotation and grasping motor imagery) and Task Side (2 levels: left vs. right) as within-subjects variables. Overall, significant differences were observed as a function of Visualization Modality. This main effect indicates that largest ERD was obtained with a 3-dimensional visualization modality. ANOVA revealed a significant interaction of 'VM' x 'Task Side' x 'Electrode Position' ($F_{3.01}$ = 8.77, p<0.001), 'VM' x 'Task' ($F_{2.22}$ = 5.45, p<0.005) and a significant interaction between electrode position and side of the motor imagery (Electrode Position x Task Side; $F_{(1,56)}$ = 18.25, p=0.001). Largest enhancement in the mu band event related desynchronisation was obtained in the tasks: '3D arm mi left' on the right hemisphere at electrode position CP4 (t = 2.75, p<0.005), '3D arm mi right' on the left hemisphere at CP3 (t = 2.62, p<0.005) and '3D hand mi left' on the right hemisphere at CP4 (t = 2.64, p<0.005), compared to the 2-dimensional task.

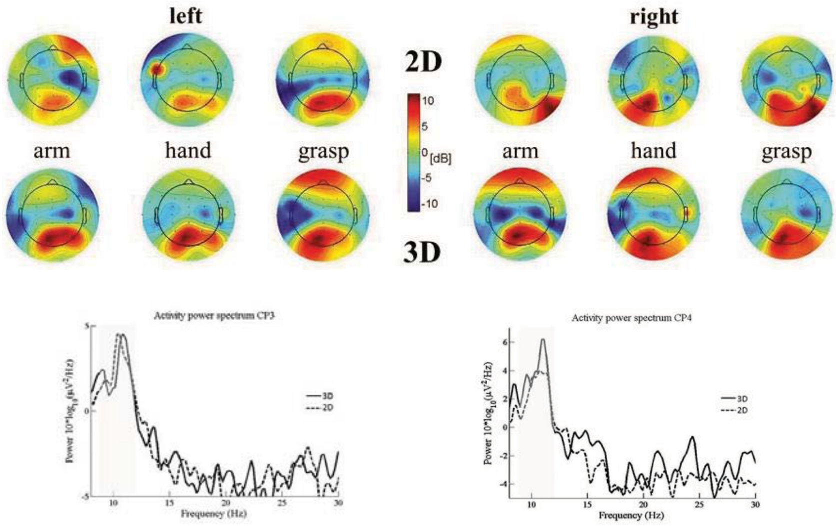

Figure 2: Maps displaying the topographical distribution of mu band power (10-12 Hz; ERD) during motor imagery tasks (left and right upper limb) after presenting 2D and 3D limb movement visualizations. The two graphs show the modulated power spectral density during motor imagery (averaged 15 participants, baseline corrected).

4 Discussion

Our findings support the assumption that stimulus-rich and realistic feedback conditions can lead to stronger motor cortex activation during motor imagery (Pineda et al., 2003; Pfurtscheller et al., 2007). Depending on the visualization modality different activations of the hemispheres could be detected corresponding to the two different electrode positions CP4 and CP3. Furthermore, this motor cortex activation was also related to the three different motor imagery tasks depending on the type of visualization. Participants were able to enhance the desired electrophysiological signals significantly in three of the 3-dimensional tasks and according to findings of Neuper et al. (2009) a contralateral dominance of the ERD was detectable. In the tasks where the 2-dimensional visualization lead to comparable strong ERDs the visualization seemed to become closely associated to the MI task and no additional benefit could be gained from the sensory richer realistic 3D visualization.

5 Conclusion

Motor imagery offers a promising technique for motor rehabilitation (Cincotti et al., 2012). With a realistic visualization of the limb movements, we tried to increase motor cortex activation during motor imagery and thereby gradually improve performance in SMR based BCI tasks. These preliminary results suggest that the patient´s involvement in the motor imagery task and the functional outcome in the motor related potentials may be improved by the use of the 3-dimensional visualization modality.

6 Acknowledgement

This work was funded by the Deutscher Akademischer Austauschdienst (DAAD), the Department of Mechanical Engineering at the Curtin University (Perth/ Western Australia) and partly supported by the GK Emotion and the EU grant FP7-ICT-2011 “CONTRAST” project.

7 References

Allison, B.Z., Wolpaw, E.W. and Wolpaw, J.R. (2007) Brain–computer interface systems: progress and prospects. *Expert Review of Medical Devices*, Vol. 4, No. 4, 463-474.

Cincotti, F., Pichiorri, F., Arico, P., Leotta, F., de Vico Fallani, F., del R Millan, J., Molinari, M. and Mattia, D. (2012) EEG-based Brain-Computer Interface to support post-stroke motor rehabilitation of the upper limb. *Proceedings of the 34th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, San Diego, CA*, pp. 4112-4115.

Kübler, A., Kotchoubey, B., Kaiser, J., Wolpaw, J.R. and Bierbaumer, N. (2001) Brain–computer communication: Unlocking the locked in. *Psychological Bulletin*, Vol. 127, No. 3.

Kübler, A., Nijober, M.S., Mellinger, J., Vaughan, T.M., Pawlzik, H., Schalk, G., McFarland, D.J., Birbaumer, N. and Wolpaw, J.R. (2005) Patients with ALS can use sensorimotor rhythms to operate a brain-computer interface. *Neurology*, Vol. 64, No. 10, pp. 1775-1777.

Neuper, C., Scherer, R., Wriessneggerand, S. and Pfurtscheller, G. (2009) Motor imagery and action observation: Modulation of sensorimotor brain rhythms during mental control of a brain–computer interface. *Clinical Neurophysiology*, Vol. 120, Issue 2, pp 239-247.

Pfurtscheller, G., Scherer, R., Leeb, R., Keinrath, C., Neuper, C., Lee, F. & Bischof, H. (2007) Viewing Moving Objects in Virtual Reality Can Change the Dynamics of Sensorimotor EEG Rhythms. *Presence* ,Vol. 16, No.1, pp 111-118.

Pichorri, F., De Vico Fallani, F., Cincotti, F., Babiloni, F., Molinari, M., Kleih, S.C., Neuper, C., Kübler A. and Mattia, D. (2011) Sensorimotor rhythm-based brain–computer interface training: the impact on motor cortical responsiveness. *J. Neural Eng*., Vol.8, No.2, 025020.

Pineda, J.A., Silverman, D.S., Vankov, A. and Hestenes, J. (2003) Learning to control brain rhythms: making a brain–computer interface possible. *IEEE Trans Neural Syst Rehabil Eng*, 11, pp. 181–184.