Proceedings of the 3rd International Brain-Computer Interface Workshop and Training Course 2006

September 21-24 2006
Graz University of Technology, Austria

G.R. Muller-Putz, C. Brunner, R. Leeb, R. Scherer,
A. Schlögl, S. Wriessnegger, G. Pfurtscheller

Verlag der Technischen Universitat Graz 2006

Laboratory of Brain-Computer Interfaces
Institut fur Semantische Datenanalyse/Knowledge Discovery
Graz University of Technology, Austria

Verlag der Technischen Universitat Graz
http://www.ub.tugraz.at/Verlag

ISBN-10: 3-902465-46-8
ISBN-13: 978-3-902465-46-7

Bibliografische Information der Deutschen Bibliothek:
Die Deutsche Bibliothek verzeichnet diese Publikation in der
Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über
http://dnb.ddb.de/ abrufbar.

Printed by TU Graz/Büroservice, Graz, Austria

MOVEMENT ONSET RELATED CHANGES IN ECOG RECORDINGS

Julie Blumberg[1,2,3], Andreas Schulze-Bonhage[1,2], Carsten Mehring[1,4], Ad Aertsen[1,3], Tonio Ball[1,2]

[1] Bernstein Center for Computational Neuroscience, Freiburg, Germany
[2] Epilepsy Center, University Hospital, Albert-Ludwigs-University, Freiburg, Germany
[3] Neurobiology & Biophysics, Institute of Biology III, Albert-Ludwigs-University, Freiburg
[4] Neurobiology & Animal Physiology, Institute of Biology II, Albert-Ludwigs-University, Freiburg

E-mail: julie.blumberg@uniklinik-freiburg.de

SUMMARY:
In former studies on movement direction inference during self-paced movement, our group found the highest decoding power in electrodes in primary and premotor cortex, but less information in inferior parietal regions [1]. In the present study we have detected groups of electrodes with a reproducibly similar dynamic behavior around movement onset irrespective of movement direction. In contrast to directional decoding, movement onset related changes showed an additional peak in the inferior parietal lobule (IPL). The IPL therefore is a promising region for movement detection in brain-machine-interfacing applications.

INTRODUCTION

For brain-machine interfacing aiming at the restoration of movement capabilities in paralysed patients it is not only crucial to extract movement parameters such as movement direction from brain signals, but it is also important to distinguish movement per se from rest, i.e. to achieve movement detection. In an ongoing project we have shown that movement direction specific electrocorticographic signals (ECoG) are generated in the human frontal lobe, allowing for single trial decoding of arm movement direction [1]. In this work, we have investigated arm movement direction *un*specific potentials which might still be useful for detection of movement in ongoing recordings.

MATERIALS AND METHODS

An epilepsy patient with electrodes implanted for pre-neurosurgical diagnostics (Fig. 1) performed center-out arm reaching movements to four targets. To record ECoG we used a densely spaced electrode grid of 112 electrodes with 4 mm diameter covering an area of approximately 7 cm x 7 cm of the fronto-temporo-parietal cortex. The function of the cortex underlying the individual electrode contacts was determined by direct electrical cortical stimulation. We investigated ECoG time series of +/- 2 seconds around movement onset.

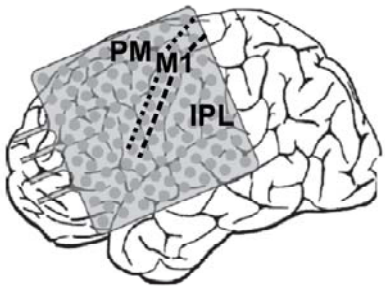

Figure 1: Subdural Electrocorticogram grid on the premotor (PM), primary motor cortex (M1) and the inferior parietal lobule (IPL). Modified from [2].

In order to identify optimal electrodes for movement detection, we developed the following three step procedure:
1) *Detection of electrodes with a reproducible movement onset behavior across trials:* For each electrode the pair wise correlation between all 88 trials in different directions was calculated and the significantly reliable electrodes were determined. The significance level was assessed by comparison with the distribution of equally preprocessed white noise.
2) *Classification of groups of electrodes with similar response:* To classify different groups of electrodes exhibiting a similar averaged temporal behavior around movement onset, we used a correlation based hierarchical clustering with distance metric

$$d = 1 - |\langle x_i(t), x_j(t) \rangle|,$$

with $x_i(t)$ being the ECoG signal of electrode i at time point t.

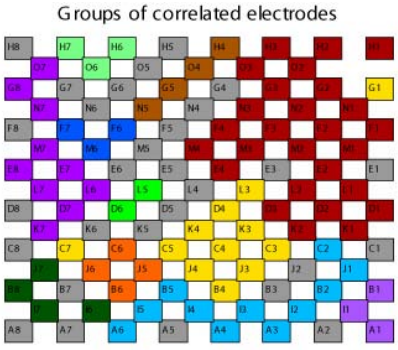

Figure 2: For a threshold correlation of 0.65, the clustered electrodes formed twelve distinct groups

3) *Determination of electrodes with specific movement onset behavior:* In the third part of our analysis we determined the electrodes with the highest significance of ECoG differences between pre- and post-movement onset periods. Therefore we tested whether a channel's mean potential over all trials irrespective of movement direction at a pre-movement time point was significantly different from the mean potential of the distribution of any of the following time points using a Student's t-test. The significance of the signal change is visualized in Fig. 3. The dark areas in the center of lighter ones indicate highly significant differences between pre-movement potentials and later movement related potentials.

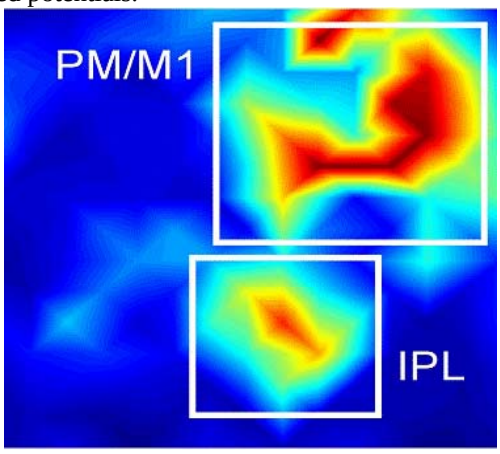

Figure 3: Areas of electrodes with significant potential differences before and after movement onset

RESULTS

Groups of electrodes with a reproducible, similar potential behavior around movement onset were detected. Electrodes above motor cortex gave the most reproducible movement onset related ECoG response. With a threshold correlation of 0.65, twelve groups of recording channels could be determined (Fig. 2). The remaining thirty electrodes were not correlated. The two largest groups of similarly behaving electrodes were located around the superior part of the central sulcus (darkest gray) as well as in the inferior part of the postcentral gyrus and the inferior parietal lobule (IPL) (lightest gray). Regarding the differences between pre- and post-movement onset time series, in the resulting cortical map (Fig. 3) local peaks were not only found in the primary motor cortex (M1) and premotor cortex (PM), marked by the upper white box, but also in a second area in the inferior parietal lobule.

DISCUSSION

As a preparation for future online movement detection for BMI applications, we investigated the temporal behavior of cortical potentials around movement onset. Based on a cluster analysis, the two largest groups of correlated electrodes were found in the region of PM/M1 and of IPL. Generally, the IPL is often found to be activated during voluntary movement tasks [3,4] and shows activity already early during movement preparation [3]. The same two regions also showed significant differences between pre- and post-movement onset ECoG amplitude. As these two areas were separated by the cluster analysis, it will be interesting to further investigate whether the two regions actually contain non-redundant information about movement onset. Further, by combining the most efficient electrodes, movement detection could be facilitated for future online analysis where movement onset is unknown.

CONCLUSION

Among the discovered robust electrodes, several groups with similar movement onset specific behavior could be identified. The two largest groups were located above PM/M1 and IPL, respectively. Such groups of electrodes may be helpful for an online application where averaged signals can not be obtained from several trials, but across a group of electrodes.
Highly significant differences between pre-movement potentials and potentials occurring later during movement preparation and execution were located not only in the region of the primary motor arm and hand representations, where ECoG signals were also movement direction specific, but an additional maximum in the topographical distribution was found in the inferior parietal cortex. Therefore, in addition to M1 and PM, this region might be a useful source of information for movement detection in BMI applications.

ACKNOWLEDGEMENTS

Supported by the WIN-Kolleg of the Heidelberg Academy of Science. BMBF-DIP D3.2 and BMBF 01GQ0420 to BCCN-Freiburg.

REFERENCES

[1] Ball T., Schulze-Bonhage A., Aertsen A., Mehring C. Inference of Arm Movement Direction from Epicortical Field Potentials of the Human Frontal Lobe. Submitted.
[2] Ball, T, Nawrot, MP, Schulze-Bonhage, A, Aertsen, A, Mehring, C (2004) Towards a brain-machine interface based on epicortical field potentials. Biomed. Eng. (Berlin), 49 (Suppl. 2), 756-759.
[3] Ball T, Schreiber A, Feige B, Wagner M, Lücking CH, Kristeva-Feige R. The role of higher-order motor areas in voluntary movement as revealed by high-resolution EEG and fMRI, Neuroimage. 1999 Dec;10(6):682-94.
[4] Mehring, C, Nawrot, MP, Cardoso de Oliveira, S, Vaadia, E, Schulze-Bonhage, A, Aertsen, A, Ball, T (2005) Comparing information about arm movement direction in single channels of local and epicortical field potentials from monkey and human motor cortex. J.Physiol. (Paris) 98:498-506.