Neural Decoding and Brain Machine Interfaces Based on Electromagnetic Oscillatory Activities: A Challenge for MEG

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Abstract One of the technological challenges in neuromagnetism is to establish a method for neuromagnetic measurement of high gamma band activities on a sigle trial basis. This would enables not only accurate neural decoding using MEG, but would also allow phase analyses revealng coupling phenomena between the gamma and other bands.

Keywords Neural decoding · Brain machine interfaces · Electrocorticography · Magnetoencephalography · Oscillations

1 Functional Mapping Using the Magnetoencephalogram

Electromagnetic measurements and analyses of cerebral oscillatory activities have spawned the new field of neuromagnetism. The electroencephalographic analyses conducted by Pfurtscheller on event-related desynchronizations and synchronizations during finger movements was the first study in this field (Pfurtscheller and Aranibar 1977). Since then, a number of studies have established that desynchronization in the alpha to low gamma bands well reflects functional localization of motor, somatosensory and language functions (Hirata et al. 2010, 2002; Taniguchi et al. 2000). Language dominance and localization may also be evaluated noninvasively and can now be investigated as a pre-surgical evaluation (Hirata et al. 2010, 2004). Sliding time window analyses have also revealed temporal profiles of language processing (Goto et al. 2011). However, it is still difficult to record

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S. Supek and C. J. Aine (eds.), *Magnetoencephalography*,
DOI: 10.1007/978-3-642-33045-2_22,

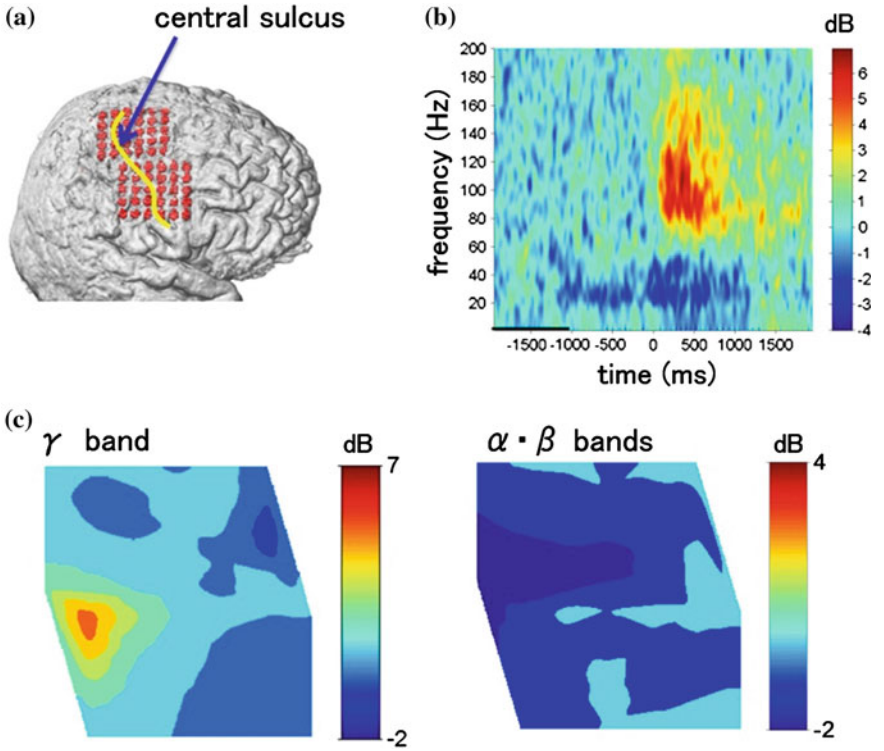

Fig. 1 Spatiotemporal distribution of oscillatory changes during hand grasping, **a** the location of the implanted electrodes, **b** a time-frequency spectrogram, **c** spatial distribution of high gamma band activities (*left*) and alpha and beta desynchronizations (*right*)

neuromagnetic high gamma activities with stability on a single trial basis, and high gamma band activities are not consistently visible on MEG without time-locked stimulation and multi-trial data (Hirata et al. 2002).

2 Brain Machine Interfaces Using the Electrocorticogram

Electrocorticograms provide us with high gamma band activities on a single trial basis. The spatial distribution of high gamma band activities is more focal than that of alpha and beta desynchronizations, and well reflects somatotopic representations (Fig. 1) (Yanagisawa et al. 2011). Using electrocorticographic high gamma activities, we can perform accurate neural decoding as well as the real time control of a robotic arm (Yanagisawa et al. 2011, 2012a). More recently, electrocorticographic phase analyses have revealed cross frequency coupling and phase amplitude coupling in the motor cortex (Yanagisawa et al. 2012b).

3 Neuromagnetic Neural Decoding

Neural decoding using neuromagnetic signals is still a relative newcomer compared to electrocorticographic decoding. Magnetic amplitude as a parameter decodes upper limb movements with high accuracy, while decoding using oscillatory activities does not allow for high accuracy (Sugata et al. 2012a, b). This is probably because it is difficult to pick up weak gamma band activities using MEG. Therefore, one of the technological challenges in neuromagnetism is to establish a method for neuromagnetic measurement of high gamma band activities on a single trial basis. This would enable not only accurate neural decoding using MEG, but would also allow phase analyses revealing coupling phenomena between the gamma and other bands.

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