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EDITORIAL

Discussing Gamma

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This issue of Brain Topography contains a series of invited short discussion articles on gamma-range high frequency oscillations. A letter from Alexander J. Shackman, indicating that one of a recently published article in Brain Topography on frontal gamma oscillations did not consider the possible contamination of facial EMG artifacts, initiated this special topic. This was during the same time that Shlomit Yuval-Greenberg et al. (2008) published a seminal article demonstrating high correlation of miniature saccades with transient induced gamma-band response measured with the EEG. In this paper the authors also demonstrated that proper inspection of the scalp topography of the electric potential would most probably have avoided the misinterpretation of previous data as occipital gamma oscillations, since the potential map shows a very strong gradient towards the nose reference. Since *Brain Topography*, as the name indicates, is much concerned with the proper analysis of the topography of the brain electric/magnetic fields, we decided to ask some of the most important groups in this ongoing discussion for a short summary of their opinion. We are very happy that they positively replied to this request and we are proud to present their articles in this issue of *Brain Topography*.

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The first article is written by Yuval-Greenberg and Deouell (2009) from the Hebrew University of Jerusalem in Israel. It is entitled *"The broadband transient induced gamma-band response in EEG reflects an increase in the rate of saccades"*. This article summarizes their findings on the relation between saccades and induced Gamma activity published in the paper mentioned above. It further stresses the caution that has to be taken when interpreting induced Gamma Band responses as neuronal synchronization. It also points out that even source localization procedures applied to EEG or MEG Gamma activity can be misleading, if the solution space of the head model is restricted to the gray matter and excludes extra-cerebral sources.

Since these saccades are roughly time locked to the stimulus and are appearing quasi after each stimulus, they can neither be rejected nor averaged out. The authors thus conclude that the only reasonable procedure to avoid misinterpretation of such artifacts is to develop methods for correction of the data.

Such correction algorithms are discussed in the second article written by Shackman et al. (2009) from the University of Wisconsin in the USA. The article is entitled "*Electromyogenic artifacts and electroencephalic inferences*" and critically evaluates techniques designed to separate neural signals from biological artifacts, in their example electromyogenic activity. They particularly test the performance of independent component analysis (ICA) and convincingly demonstrate that ICA may not adequately separate MEG from EEG signals in high-density recordings.

The difficulty of properly removing myogenic artifacts is particularly important for studies on EEG activity in the Gamma range, given the fact that EMG activity has similar spectral profiles. In addition, particularly facial EMG activity can be sensitive to experimental manipulations in the same way as neural Gamma activity. This has been explicitly tested in a recent study on paralysed human volunteers during the execution of different cognitive tasks (Whitham et al. 2007). The results of these studies and new data are reported in the article by Pope et al. (2009) from the Flinders University in Adelaide, Australia. It is entitled: "*Relation of gamma oscillations in scalp recordings to muscular activity*." While these studies clearly demonstrate a large contribution of muscle activity on the spectral power and the coherence in unparalysed as compared to paralysed subjects, it also shows that even in paralysed subjects target stimuli still can induce enhanced EEG activity in the gamma range, demonstrating that neuronal gamma activity can still be measured with the scalp EEG.

While it is undisputable that scalp EEG and MEG is largely contaminated by myogenic and ocular artifacts, it is thought that this is much less the case for electrical activity recorded intracranially. Such recordings can be performed in patients undergoing invasive presurgical epilepsy evaluation. The group from the University Claude Bernard in Lyon, France has repeatedly demonstrated intracranial gamma-band oscillations related to different cognitive tasks (e.g. Tallon-Baudry et al. 2005). In the article by Jerbi et al. (2009) from Lyon and Paris, the group critically evaluated the contribution of saccadic eye movements to gamma-band power increase in intracranial recordings. In this paper entitled "*saccade related gamma-band responses in intracerebral EEG: dissociating neural from ocular muscle activity*" the authors show that such myogenic artifacts are picked up by intracranial electrodes in the temporal pole because of its vicinity to extraocular muscles. However, intracranial electrodes in other brain structures are not influenced by activities of these muscles and clearly show neuronal gamma activity related to cognitive tasks.

Given the fact that neuronal Gamma activity indeed exists (despite the difficulty to dissociate it from muscle activity), the question remains on the functional significance of these oscillations. Schroeder and Lakatos (2009) from the Nathan S. Kline Institute for Psychiatry Research in New York, USA, discuss this question in the article with the provoking title "*The gamma oscillation: master or slave*". They point out the fact that gamma amplitude is often coupled to the phase of lower frequency oscillations, and that these lower frequency oscillations are often tuned to the rhythm with which task-relevant stimuli are received or sampled by motor behavior. The alignment of the brain rhythm to the relevant stimuli permits optimal stimulus discrimination during high excitability phases. It is during these high excitability phases that gamma amplitude increases. In consequence, gamma synchrony in theses cases would only be secondary to the high excitability phase that is determined by lower frequency rhythms, such as alpha. In this sense, gamma might not necessary be the rhythm that is critical for processing of task-relevant stimuli.

All together, we think that these 5 special topic articles on the generation and significance of gamma activity highlight the major critical points of caution when exploring high frequency oscillations with EEG and MEG recordings. While there is no doubt that Gamma activity is crucial for neuronal excitability, the exclusive role of this rhythm for "binding" information in large-scale brain networks may be doubtful given the obvious falsification of some of the initial reports on induced gamma activity.

References

Jerbi K, Freyermuth S, Dalal S, Kahane P, Berthoz A, Bertrand O, Lachaux J-P (2009) Saccade related gamma-band responses in intracerebral EEG: dissociating neural from ocular muscle activity. Brain Topogr 21(3) (this issue)

Pope KJ, Fitzgibbon SP, Lewis TW, Whitham EM, Willoughby J (2009) Relation of gamma oscillations in scalp recordings to muscular activity. Brain Topogr 21(3) (this issue)

Schroeder C, Lakatos P (2009) The gamma oscillation: master or slave. Brain Topogr 21(3) (this issue)

Shackman AJ, McMenamin BW, Slagter HA, Maxwell JS, Greischar LL, Davidson RJ (2009) Electromyogenic artifacts and electroencephalic inferences. Brain Topogr 21(3) (this issue)

Tallon-Baudry C, Bertrand O, Henaff MA, Isnard J, Fischer C (2005) Attention modulates gamma-band oscillations differently in the human lateral occipital cortex and fusiform gyrus. Cereb Cortex 15:654–662

Whitham EM, Pope KJ, Fitzgibbon SP, Lewis T, Clark CR, Loveless S, Broberg M, Wallace A, De LosAngeles D, Lillie P, Hardy A, Fronsko R, Pulbrook A, Willoughby JO (2007) Scalp electrical recording during paralysis: quantitative evidence that EEG frequencies above 20 Hz are contaminated by EMG. Clin Neurophysiol 118:1877–1888

Yuval-Greenberg S, Deouell L (2009) The broadband transient induced gamma-band response in EEG reflects an increase in the rate of saccades. Brain Topogr 21(3) (this issue)

Yuval-Greenberg S, Tomer O, Keren AS, Nelken I, Deouell LY (2008) Transient induced gamma-band response in EEG as a manifestation of miniature saccades. Neuron 58:429–441