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RESEARCH**

Review

Enhanced gamma-band activity in ADHD patients lacks correlation with memory performance found in healthy children

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ARTICLE INFO

Article history:

Accepted 10 June 2008

Available online 19 June 2008

Keywords:

40 Hz

Dopamine

Encoding

Gamma activity

Polymorphism

Oscillations

ABSTRACT

Previous electrophysiological as well as imaging research has contributed to the understanding of impairments in attention, executive functions, and memory in patients with attention-deficit/hyperactivity disorder (ADHD). However, there is a lack of studies investigating ADHD related differences in the gamma range of human electroencephalogram (EEG), although gamma activity is strongly associated with cognitive processes impaired in ADHD patients and is also modulated by dopamine polymorphisms linked with ADHD. To close this gap, the present study compared gamma activity in ADHD children with that of healthy controls and correlated it with memory performance. EEG was recorded from 13 ADHD patients as well as 13 healthy control subjects during the encoding phase of a visual memory paradigm. In a subsequent recognition test, participants had to judge pictures as being old or new. Analysis of evoked gamma-band responses (GBRs) during stimulus encoding revealed a strong task-related enhancement for ADHD patients in parieto-occipital areas. Interestingly, this augmentation was not associated with recognition performance, whereas healthy subjects exhibited a strong positive correlation between evoked gamma activity during stimulus encoding and subsequent recognition performance. We interpret this finding as evidence of enhanced excitation levels and unspecific activation of processing resources in ADHD patients. Furthermore, enhanced GBRs in ADHD could also indicate a decrease of neuronal signal-to-noise ratio, partially caused by the genetic variations within the dopaminergic pathway of ADHD patients. The involved genetic polymorphisms have been shown to modulate evoked GBRs, which therefore could be a possible marker of impaired neurotransmission in ADHD.

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Contents

1. Introduction	118
1.1. A short review of oscillatory EEG abnormalities in psychiatry	119
1.1.1. Alzheimer's disease	119
1.1.2. Schizophrenia	119
1.1.3. Attention-deficit/hyperactivity disorder	120
2. Results	121
2.1. Behavioral performance	121
2.2. Evoked gamma activity	121
2.3. Associations between behavioral performance and evoked GBR	121
2.4. Total activity	121
3. Discussion	121
3.1. Group differences in evoked GBR	121
3.2. Association between evoked GBR and subsequent memory performance	123
3.3. Possible interactions of ADHD neurobiology and evoked GBR	124
4. Conclusions	124
5. Experimental procedures	124
5.1. Participants	124
5.2. Stimuli and task	125
5.3. Data acquisition	126
5.4. Data analysis	126
5.4.1. Behavioral data	126
5.4.2. Electrophysiological data	126
5.4.3. Statistical analysis	127
Acknowledgments	128
References	128

1. Introduction

Even in the new era of functional neuroimaging, the electroencephalogram (EEG) still represents an important tool for brain research as well as neurology and psychiatry. The EEG reflects the electrical activity of large populations of synchronized neurons — mostly cortical pyramidal neurons. Therefore, some diseases can more easily be identified with EEG than with functional imaging, especially when the disease manifests in the form of altered electrical brain activity as it is the case e.g. in epilepsy. Furthermore, many psychiatric diseases correlate with certain EEG changes. Such changes can either serve as biological markers for diagnostic purposes or for an understanding of the cognitive functions which are disturbed in that disorder. In order to be useful as a biological marker, an EEG change needs to meet two requirements. It has to be both sensitive and specific. Criteria for how to investigate EEG changes of psychiatric patients for the purpose of brain research are less well defined.

Some studies compare a group of healthy controls with a group of patients and report significant differences between certain EEG parameters. While this may be useful for diagnosis, it does not immediately further our understanding of brain function. [Başar and Güntekin \(2007\)](#) recently requested EEG researchers to correlate their findings with cognitive functions. The authors suggested to use a canonical set of cognitive functions and to demonstrate that EEG parameters reflect certain aspects of these functions in order to improve the comparability of findings and to make them

easier to interpret. The same should be required for patient studies when they are intended to reveal new insights about cognitive brain functions.

A potential strategy to achieve this goal would be the following. First, one could identify the cognitive deficit which a patient group suffers from. Then EEG correlates of this cognitive function should be searched for in the literature. Within the study, patients should not be passively recorded but should perform a cognitive task which will yield a measure assessing their deficit as compared to the control group. The EEG correlate of this cognitive function should be correlated with the deficit. If, in fact, the size of the EEG correlate scales with the cognitive deficit, this would be a strong indication for the former being a correlate of the latter. In this case, the study can indeed further our understanding of both the cognitive function and its disorder. For a more detailed description of such an approach see [Barceló and Gale \(1997\)](#).

The approach of using event-related potentials (ERPs) in psychiatry goes into this direction. ERPs are recorded from patients in a cognitive experiment and are correlated with the impairments. In addition, examination of event-related activity, where ongoing EEG is averaged in relation to specific events such as stimulation or responses, allows analysis of the time course of brain activation following or preceding these events in the range of milliseconds. See [Pogarell et al. \(2007\)](#) and [Banaschewski and Brandeis \(2007\)](#) for reviews on that topic. In the sequel we want to focus on oscillatory activity instead of ERPs.

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