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Alpha oscillations as a correlate of trait anxiety

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Abstract

The associations among psychometric measures of anxiety and depression and individually adjusted electroencephalogram (EEG) spectral power measures registered in resting condition and during experimental settings were investigated in 30 males aged 18–25 years. During all stages of registration, Taylor Manifest Anxiety and Spielberger state anxiety (SA) and trait anxiety (TA) scores were positively related to alpha and negatively to delta relative power with these relations being independent of cortical site. Within-subject estimate of the strength of reciprocal relationship between alpha and delta oscillations (alpha–delta anticorrelation, or ADA) was positively related to trait anxiety and depression. Three minutes after an alarming event (unexpected loud sound), a further increase of alpha power was observed. In low-anxiety subjects, this increase was mostly associated with fast alpha (alpha 3), whereas in high-anxiety ones, it was mainly linked to slow alpha (alpha 2). SA mediated relationship between TA and EEG power, while ADA and alpha band reactivity showed trait-like features being associated with TA even after accounting for SA. These findings are interpreted as an indication of higher vigilance and higher reactivity of alpha system in anxious individuals.

Keywords: EEG; Brain oscillations; Personality; Anxiety; Depression

1. Introduction

Basar (1998), in his fundamental book on brain oscillations, points out that a great change is taking place in neuroscience due to the fact that brain scientists have recognized the importance of oscillatory phenomena and the functional electroencephalogram (EEG). A particularly important landmark in this book is the emphasis given to the alphas (i.e., distributed oscillatory processes in the 10-Hz frequency range). This great change has been fostered by development of new methodological approaches including "methods of thoughts" (Basar, 1998). Brain oscillations recorded in a form of spontaneous or evoked EEG could be considered as a kind of message carrying important information about intrinsic modes of brain activity. Given potential importance of this message, usage of EEG in psychology research seems inevitable.

Knyazev and Slobodskaya (2003) proposed an evolutionary-based interpretation of brain oscillations relevant for research of EEG correlates of personality. Using as a starting point the concept of triune brain introduced by MacLean (1985), Knyazev and Slobod-

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skaya (2003) suggested that delta, theta, and alpha oscillations reflect activities of three hierarchical philogenetic brain systems. Delta oscillations are linked with the most ancient system, which was dominant in reptilian brain. Theta oscillations dominate in lower mammals. Alpha oscillations are manifestations of activities of the newest system, which dominates in adult humans. The three hierarchical phylogenetic systems fulfill parallel processing, and their contribution to resulting behavior could differ in different individuals. The strength of reciprocal relationships between these systems and the relative prevalence of some oscillations over others relate to stable behavioral patterns relevant to personality and psychopathology.

According to MacLean's concept, the reptilian brain consists of the brainstem, cerebellum, and basal ganglia. Superimposed on this brain in the course of evolution is the brain of lower mammals, which added the limbic system. Finally, the third brain appeared in advanced mammals and primates in the form of added neocortex. It is important to emphasize that we do not equate exactly the three oscillatory systems with anatomical structures included in the three brains of the MacLean model; we just borrow his evolutionary idea. It should be kept in mind that the MacLean model is a theoretical construct, whereas the three oscillatory systems are empirical entities. So we could just look for existing data about evolution and distribution of these systems. Comparative studies by Bullock indicate that the most striking evolutionary puzzle is a general consistent difference in the power spectrum of EEG between all vertebrates and all invertebrates. This difference concerns the synchrony of slow waves (< 50 Hz), which is dramatically higher in vertebrates. Invertebrates have much more obvious unit spiking than vertebrates, but much less relative amplitude of slow waves (Bullock, 1993). Among vertebrates, the degree of synchronization also increases during evolution. There is an evidence of less synchrony or more rapid coherence decline with distance in reptiles, amphibians, and fish than in mammals (Bullock, 1997). Beyond this, the power spectra look alike in all the vertebrates, falling quite steeply on each side of a maximum around 5–15 Hz (Bullock, 1993). Oscillations of delta, theta, and alpha frequencies could be found in each vertebrate (Basar, 1998). But there is an important distinction between reptiles, lower mammals, and humans in what frequency dominates in the scalp EEG. Alpha is the dominant frequency in adult humans, while theta dominates in the EEG of lower mammals (Klimesch, 1999) and delta in the reptilian EEG (Gaztelu et al., 1991; Gonzalez et al., 1999). That means that all three oscillatory systems were acquired early in the evolution of vertebrates, but they further developed with different rates. Development of delta system peaks in reptiles, theta in mammals, and alpha in primates. The three oscillatory systems do not have to exactly match anatomically the three brains of the MacLean model. They might be selectively distributed over the entire brain (Basar, 1998, 1999), although the main populations of neurons representing these systems must be located within respective brains.

Following MacLean, one might speculate about physiological and behavioral correlates of these systems. The most ancient delta system deals with internally driven behavior oriented to acquisition of biologically important goals, such as survival, physical maintenance, dominance, and mating. Among environmental signals, this system mostly recognizes those relevant to biologically important motives or current goals. Interestingly, randomly distributed splashes of delta activity have been repeatedly registered during presentation of target stimuli in P300 experimental paradigm (Basar, 1998). Increase in delta power might be expected in states of increased biological motivation (e.g., sexual). Indeed, Schutter and van Honk (in press) have recently shown that in healthy male volunteers, administration of testosterone, which presumably enhances sexual motivation, significantly increases the delta power. In children, prevalence of delta oscillations has been shown to relate to parent, teacher, and self-ratings of conduct disorder (Knyazev et al., 2002b, 2003), which is also in line with the above reasoning. According to MacLean, the reptilian brain is active, even in deep sleep, since it controls autonomic functions, such as breathing and heartbeat. That explains why delta is the most salient rhythm during the slow-wave sleep.

Theta system operates in close conjunction with the delta system, but it is linked with more flexible behavior regulation, which implies the matching of internal drives with acquired during lifetime experience. Alpha system is engaged in perception and recognition of environmental patterns. Increase of