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Event-related variations in alpha band activity during an attentional task in preadolescents: Effects of morning nutrition

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Abstract

Objective: Event-related desynchronization and synchronization (ERD/ERS) methodology was used to study interactions between nutrition, brain function, cognition and behavior in children who ate or skipped breakfast after overnight fasting.
Methods: Healthy preadolescents performed a cued visual Go/No-Go RT task after overnight fasting (Phase 1) and again (Phase 2) after eating breakfast ($n = 30$) or continuing to fast ($n = 30$). ERS and ERD determinations (8–10, 10–12 Hz; frontal, central, parietal, occipital sites) and measures of sleep (overnight actigraphy) and blood glucose (finger sticks) were obtained.
Results: Feeding increased blood glucose, but the groups were similar in sleep amount and response accuracy. Between-phase comparisons showed slower RT and increased alpha synchronization in fasting subjects, but little change in those who ate breakfast. Phase 2 group differences emphasized greater frontal early ERS and late frontal–central ERD in Fed subjects.
Conclusions: In preadolescents a brief extension of overnight fasting resulted in significant changes in brain activity and behavior that were effectively countered by eating breakfast. Delaying breakfast until mid-morning appeared to have introduced fasting effects that attenuated responses in Fed subjects.
Significance: These findings show the sensitivity of brain function and behavior to subtle variations in nutritional status and argue for greater consideration of nutritional variables in neurobehavioral studies.

Keywords: Event-related desynchronization/synchronization; Preadolescents; Fasting; Nutrition; Go/No-Go; Reaction time

1. Introduction

Breakfast is arguably the most important meal of the day. It provides fuel and nutrients to the central nervous system following what is generally the longest daily period of going without food, i.e., overnight fasting. Among the consequences of this period of extended fasting is a reduction in levels of blood glucose (Scheen et al., 1996; Shea et al., 2005), and blood-borne glucose is considered the most important energy source of the central nervous system (Hertz and Dienel, 2002; La Fleur, 2003) and fundamental to cognitive activity (Gold, 1995; Benton and Parker, 1998; Dye et al., 2000).

Morning nutrition is especially important for children because of their greater energy requirements (Chugani et al., 1987) and relatively reduced energy stores. The average child up to about 10 years of age needs to eat every 4–6 h to maintain a blood glucose level sufficient to adequately support the activity of the brain, and the liver of the child – being much smaller than that of an adult – has a glycogen store that lasts only about 4 h (Whitney and Rolfes, 1996). Intuitively, then, morning nutrition – particularly in children – must be of benefit to both

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physical health and cognitive functioning, and there is empirical evidence to support this assertion. For example, children who skip breakfast show deficits on memory and behavioral tests (see Pollitt and Mathews, 1998; Dye et al., 2000 for reviews), and children who are undernourished are more susceptible to the effects of extended morning fasting (Pollitt and Mathews, 1998). Failures to find positive effects of morning nutrition on cognitive measures (e.g., Dickie and Bender, 1982; Cromer et al., 1990; Lopez et al., 1993; Lloyd et al., 1996) may be attributable to uncontrolled confounding variables (Pollitt and Mathews, 1998).

While the effects of eating and fasting on behavioral measures in children have received a great deal of investigative attention, the effects of these nutritional conditions on neurophysiological processes underlying and often predicting cognitive behaviors have been largely neglected. For example, there have been surprisingly few studies examining the effects of morning nutrition on brain electrical activity, and virtually none in healthy school-age children. In a series of studies in young adults, Polich and colleagues reported eating-associated variations in EEG and evoked potentials consistent with enhanced arousal (Geisler and Polich, 1990, 1992a,b; Hoffman and Polich, 1998; Hoffman et al., 1999). In what appears to be the only report in which nutritional effects on both behavioral and brain electrical activity measures were studied in school-age children, Conners and Blouin (1982/83) tested children at different times across the morning on a visual Continuous Performance Task while recording event-related potentials (ERPs). They found that eating breakfast was associated with improved performance, significant reductions in central N100 amplitude and shorter latencies of early and late parietal ERP components. They concluded that these measures of attention and motor behavior appeared to be sensitive to subtle nutritional effects.

There is an obvious need for greater understanding of the interactions between nutrition, brain function, cognition and behavior in children. The present investigation provides new information relevant to these interactions by studying children in fasting and fed conditions while they are performing an attentional task, and relating phasic EEG responses to task stimuli and performance variables. The specific EEG variables selected for study are variations in the alpha frequency band – the dominant EEG rhythm in adults during wakefulness (Nunez, 1974, 1995) and characterized as "…one of the most important fundamental building blocks of function in the central nervous system." (Basar and Schurmann, 1997, p. 455). Alpha activity has shown relationships to processes important to task performance in the present study, e.g., variations in alpha activity have been related to arousal (Pivik and Harman, 1995; Cantero and Atienza, 2000), attention (Ray and Cole, 1985; Cooper et al., 2003), and sensory processing (Basar, 1999; Schurmann and Basar, 2001). Furthermore, frequencies within the alpha band covary with ERP components shown to be influenced by variations in nutrition. For example, event-related alpha responses have been described for both the N100 (Klimesch et al., 2004) and P300 ERPs (Yordanova et al., 2001) – both of which have been reported to be affected by nutritional status (Conners and Blouin, 1982/83; Geisler and Polich, 1990, 1992a,b; Hoffman and Polich, 1998; Hoffman et al., 1999). These various state and event relationships suggest that alpha band brain activity is sensitive to nutritional influences.

Among methods for quantifying stimulus-related variations in EEG the method of analysis applied in this investigation, i.e., the measurement of event (stimulus)-related desynchronization (ERD) and synchronization (ERS), has been particularly useful. These measures express EEG amplitude variations immediately following a stimulus relative to a preceding stimulus-free reference period that is commonly a neutral, resting condition (Pfurtscheller, 1977; Pfurtscheller and Aranibar, 1977). This technique has been used to study changes in EEG frequencies in relation to a wide range of conditions and variables, including different sensory modalities (Pfurtscheller, 1992), motor (Leocani et al., 2001) and cognitive (Klimesch, 1999; Neuper et al., 2005) behaviors, as well as state and trait factors (Pfurtscheller, 1992; Pfurtscheller and Lopes da Silva, 1999; Doppelmayr et al., 2005). Among the general findings of this research have been behavior-specific covariations among sub-band frequencies (Jausovec and Jausovec, 2000; Aftanas et al., 2002; Molle et al., 2002; Babiloni et al., 2004), as well as observations of frequency-specific behavioral correlates within the alpha band, e.g., differential low and high alpha effects (Klimesch, 1999; Krause et al., 2001b; Neuper and Pfurtscheller, 2001; Doppelmayr et al., 2005). With respect to the latter, low alpha effects are topographically diffuse and considered to reflect general, non-specific variations in attention and arousal (Klimesch and Pfurtscheller, 1988; Krause et al., 1995) and high alpha effects topographically restricted and task-specific (Klimesch et al., 1992, 1998).

Although there is an extensive literature using ERS/ERD measures in adults, their use in studies involving children has been more limited. However, children within the age range of those included in the present investigation, i.e., preadolescents, have shown ERS/ERD responses differing in amplitude and latency but otherwise generally comparable to those in adults on a memory task (Krause et al., 2001a; Gomarus et al., 2006). These differences were attributed to developmental factors. Klimesch et al. (2001a,b) also used phasic event-related changes in alpha band activity to differentiate clinical from non-clinical preadolescent populations on cognitive and memory performance tasks. In the present investigation ERS/ERD determinations for low and high alpha band activities at frontal, central, parietal and occipital cortical sites were made in the context of a cued visual Go/No-Go continuous performance task (CPT). This paradigm allows for the assessment of processes involved in attention, stimulus registration and evaluation, response execution or inhibition, as well as providing performance outcome measures