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Research Report

Age-related differences in working memory evoked gamma oscillations

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ABSTRACT

Objective: Working memory is associated with gamma oscillations (30–50 Hz). Previous studies have demonstrated altered gamma oscillations in the elderly population that may be related to general cognitive decline. However, it is unknown how gamma oscillations change with age or if there is an age when gamma oscillations optimally mediate working memory performance. That is, gamma oscillations may be maximal in middle-aged adults compared to younger and elderly adults. The objective of this study was to evaluate working memory evoked gamma oscillations in adults aged 19–29 years (mean 23.32±2.85 1 SD) compared to adults aged 30–60 years (mean 39.10±8.11 1 SD).

Methods: Subjects completed the verbal N-back task administered at four working loads (0, 1, 2, 3), while electroencephalography (EEG) was collected. Gamma power was measured during correct responses.

Results: Reduced gamma oscillations were observed in the adults aged 19–29 compared to those aged 30–60 years. Age was found to be positively related to the power of gamma oscillations. No differences were found on N-Back accuracy.

Conclusions: Increased working memory evoked gamma oscillatory activity may provide a neurophysiological marker in the healthy aging brain.

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1. Introduction

Working memory is a higher order cognitive process that involves the online maintenance and manipulation of information (Baddeley, 1986) that is mediated largely by the frontal cortex including the dorsolateral prefrontal cortex (DLPFC). Working memory is critical to other cognitive processes such as language comprehension, learning and reasoning highlighting its importance in everyday function (Baddeley, 1992). Evidence has demonstrated that working memory accuracy declines with age as early as 18 years of age (Craik et al., 1987; Craik and Dirkx, 1992; Rabinowitz et al., 1982; Salthouse, 2003). It is therefore possible that adults included in the typical age range of 18–60 may differ not only in working memory performance but also on the neurophysiological mechanisms underlying this cognitive process.

There are several neurobiological variables that may be associated with age effects on working memory. For example, post-mortem studies have shown that the brain undergoes developmental changes during gestation which continue into the 3rd decade of life (Benes et al., 1994; Brody et al., 1987; Hunter et al., 1997). Moreover, Van Bogaert et al. (1998) has shown that blood glucose metabolism stabilizes in the mid-twenties measured with positron emission tomography. Consistent with these findings, anatomical magnetic resonance imaging studies have established that the brain continues to mature during late adolescence and early adulthood. Notably, white matter volume increased linearly with age up until midlife (Bartzokis et al., 2001; Giedd et al., 1999a, 1999b). By contrast, gray matter reportedly increases during childhood, reaches a peak during adolescence, and then decreases during late adolescence and early adulthood (Gogtay et al., 2004; Reiss et al., 1996; Sowell et al., 2001). Furthermore, the age at which gray matter volume peaks is region-dependent. For example, studies have indicated that the dorsal, medial and lateral areas of the prefrontal cortex and posterior regions of the temporal cortex are the last regions of the brain to develop (Gogtay et al., 2004; Reiss et al., 1996; Sowell et al., 2001). Taken together, these functional and anatomical studies have demonstrated developmental changes in the brain that continue to mid-life. Such anatomical changes may be associated with neurophysiological mechanisms that underlie working memory performance.

Neurophysiological evaluation of working memory with electroencephalography (EEG) may provide an objective technique to measure of working memory decline. Specifically, both the generation, and modulation of gamma (30–50 Hz) oscillations in response to working memory load can be evaluated. For example, Howard et al. (2003) demonstrated that gamma oscillations increase with working memory load among epileptic patients. Gamma oscillations have also been shown to modulate with increased working memory load in an inverted U-shaped pattern among healthy subjects while performing the N-Back task (Barr et al., 2009) consistent with neuroimaging studies (Callicott et al., 1999). The lack of modulation of gamma oscillations has been associated with poor working memory performance. For example, Missonnier et al. (2004) demonstrated a lack of an inverted U-shaped pattern in healthy elderly adults (mean age 75 years) compared younger adults (mean age 26 years). A lack of modulation and reduced gamma oscillations was further demonstrated by Missonnier and colleagues in patients with mild cognitive impairment (Missonnier et al., 2011). These studies demonstrated that age affects both the generation and modulation of gamma oscillations in healthy elderly adults, but has yet to be evaluated in healthy younger adults.

The first objective of the study was to evaluate the effect of age on the generation and modulation of evoked gamma oscillations in adults aged 19–29 years compared to adults aged 30–60 years. It was hypothesized that adults aged 30–60 would generate greater gamma oscillations compared to adults aged 19–29; while all adult subjects would modulate gamma oscillations in response to working memory load. The second objective of this study was to examine the relationship between gamma oscillations, age, and N-back accuracy. It was hypothesized that gamma oscillations would be positively related with age and N-back accuracy.

2. Results

2.1. Subject demographics

Forty-six healthy right-handed subjects (age range was 19–60 years; mean age 30.52±9.83 1 SD; 23 males) completed the study. Subjects were allocated to adults aged (19–29 years; mean age 23.32±2.85 1 SD; males=12) and (30–60 years; mean age 39.10±8.11 1 SD; males=11). Subject demographics are listed in Table 1.

2.2. The effect of age on the extent and modulation of gamma oscillations

A factorial repeated measures ANOVA was conducted to examine the effect of age on gamma power from the frontal

Table 1 – Demographic variables separated by group, adults aged 19–29 years and adults aged 30–60 years.

Demographic variable	19–29 years (n=25)	30–60 years (n=21)
Age (years) (mean±1 SD)	23.32±2.85	39.10±8.11
Sex n (%)	Female: 13 (52%)	Female: 10 (48%)
	Male: 12 (48%)	Male: 11 (52%)
Education n (%)	Part college: 6 (24%)	Grade 7 to 12: 3 (14%)
	Graduated 4 year undergraduate: 8 (32%)	Part college: 1 (5%)
	Part graduate or professional school: 3 (12%)	Graduated 2 year College: 1 (5%)
	Completed graduate or professional school: 8 (32%)	Graduated 4 year undergraduate: 9 (43%)
		Completed graduate or professional school: 7 (33%)