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Behavioural correlates of the P3b event-related potential in school-age children

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ABSTRACT

The latency and amplitude of the P3b component of event-related potentials (ERPs) have been related to behavioural performance on several attention and memory tasks in adult populations. However, the extent to which these results apply to children is unknown. This study examined the neurobehavioral correlates of the P3b component in a longitudinal sample of school-age children from Arctic Québec. Children ($N = 110$; mean age = 11.3 years) were assessed on an ERP auditory oddball paradigm and a neurobehavioral evaluation targeting several aspects of cognition, including the Stewart Extended Continuous Performance Test (E-CPT), California Verbal Learning Test (CVLT), Stroop Color-Word Interference Test, and five subtests from the Wechsler Intelligence Scale for Children-Fourth edition (WISC-IV). P3b latency was positively related to reaction time measures and negatively associated with performance on the WISC-IV Digit Span Forward subtest. Amplitude of the P3b was associated with shorter completion time on the Stroop test and better delayed recognition memory performance among children who did not use semantic strategies on the CVLT. Profile analyses revealed no difference in scalp distribution of the P3b according to performance on these tests. The results are consistent with previous studies with older participants and suggest that, despite age-related differences in waveform and scalp distribution, the P3b component relates to similar neurocognitive processes in children and adults.

1. Introduction

The P3b is one of the most extensively studied event-related potential (ERP) components, although its function in cognitive processing continues to be debated. One general assumption is that it reflects central cognitive processes occurring with the active detection of an attended stimulus (Hansenne, 2000). Its latency is commonly used as a neurophysiologic marker of processing speed. According to the stimulus evaluation hypothesis (Kutas et al., 1977; McCarthy and Donchin, 1981), P3b latency provides an index of the duration of stimulus categorisation that is independent from response-associated processes. This hypothesis suggests that the onset of the P3b occurs after the stimulus has been accurately evaluated, but it does not specify the exact nature of the process reflected by the P3b itself or its functional role in cognitive processing.

Among the most influential theories of P3b is the context-updating theory, which suggests that the P3b is involved in memory processing. According to this theory, P3b is a manifestation of activity occurring when one's model of the environment must be revised; that is, it represents the adaptation of working memory to the changing data in the environment (Donchin, 1981; Donchin and Coles, 1988). An alternative explanation is provided by the context-closure hypothesis, which suggests the P3b represents post-decision processes occurring when expectancies about the occurrence of a target stimulus are fulfilled (Desmedt, 1980; Verleger, 1988). The latter theory does not support any role of the P3b in memory processing. Since their formulation, these models have evolved separately and there is still no consensus on whether or not P3b is directly involved in mnemonic activities (Polich, 2007; Verleger, 2008).

The function of the P3b component has been examined in an impressive number of studies conducted with adults, several of which were aimed at identifying the relation of its parameters (latency and amplitude) to behavioural performance on cognitive tasks. Table 1 summarises the results from studies using this approach with healthy adults.

In support of the stimulus evaluation hypothesis (Kutas et al., 1977; McGarry-Roberts et al., 1992; Ritter et al., 1972), P3b latency was positively associated with simple reaction time and completion time on speeded tasks in most studies (Emmerson et al., 1989;

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Table 1
Correlations between P3b parameters and behavioural performance reported in previous studies.

Neuropsychological test	Correlation coefficient		Reference
	Latency	Amplitude	
Attention			
Simple reaction time	.16*	−.14	Portin et al. (2000)
Two-choice reaction time	.12	−.08	Portin et al. (2000)
Ten-choice reaction time	.15	−.21*	Portin et al. (2000)
Symbol Digit Modalities Test	−.45** [a]	N.A.	Emmerson et al. (1989)
Digit Symbol	−.13	.19	Polich and Martin (1992)
	.30*	−.18	Egan et al. (1994)
	−.19*	.24**	Portin et al. (2000)
	−.33*	.40**	Gurrera et al. (2005)
Digit Symbol total errors	−.05	−.02	Polich and Martin (1992)
Letter cancellation hit rate (%)	−.19*	.01	Portin et al. (2000)
Letter cancellation total r time	.32**	−.29**	Portin et al. (2000)
Letter cancellation total errors	.03	−.17*	Portin et al. (2000)
Trail Making Test A (time to complete)	.27*	.20	Egan et al. (1994)
Trail Making Test B (time to complete)	.41**	.28*	Egan et al. (1994)
Trail Making Test A (scaled score)	−.25	.31*	Gurrera et al. (2005)
Trail Making Test B (scaled score)	−.33*	.15	Gurrera et al. (2005)
Memory			
Digit Span (Total)	−.36** [a]		Polich et al. (1983)
	−.18	−.01	Polich and Martin (1992)
	−.29*	−.22	Egan et al. (1994)
	−.04	−.02	Portin et al. (2000)
	−.51* [a]	.29*	Walhovd and Fjell (2002)
	−.34*	.12	Gurrera et al. (2005)
Digit Span Forward	−.37**	N.A.	Polich et al. (1983)
	−.51* [a]	.26*	Walhovd and Fjell (2002)
Digit Span Backward	−.28**	N.A.	Polich et al. (1983)
	−.38* [b]	.26* [b]	Walhovd and Fjell (2002)
Logical memory — Immediate	.06	−.22	Egan et al. (1994)
AVLT ∑ Trial 1−5	−.25*	−.41**	Egan et al. (1994)
Paired Words Immediate Recall	−.04	.13	Portin et al. (2000)
Logical memory — Delayed	.00	−.31*	Egan et al. (1994)
AVLT Delayed Recall	−.13	−.37*	Egan et al. (1994)
Paired Words Delayed Recall	−.04	.14	Portin et al. (2000)
Rey Figure Short-Delay Reproduction	.08	.09	Portin et al. (2000)
Digit Symbol incidental learning	.05	.00	Portin et al. (2000)
Visuospatial reasoning			
Raven Matrices	.00	−.01	Polich and Martin (1992)
Matrix Reasoning	−.48* [b]	.33* [b]	Walhovd and Fjell (2002)
Block Design	.02	−.17	Egan et al. (1994)
	−.14	.01	Portin et al. (2000)
	−.41* [b]	.32* [b]	Walhovd and Fjell (2002)
Object Assembly	−.09	−.23	Egan et al. (1994)
Verbal abilities			
Vocabulary	−.16	−.07	Walhovd and Fjell (2002)
	.09	.02	Gurrera et al. (2005)
Similarities	−.01	−.30*	Egan et al. (1994)
	−.08	−.01	Portin et al. (2000)
	−.25* [b]	.02	Walhovd and Fjell (2002)
Word fluency	−.29*	.03	Egan et al. (1994)

Abbreviations: N.A., Not available information.
Note. Pearson correlation analyses are reported except for Portin et al. (2000) (Spearman's partial rank-order correlations adjusting for age and education) and Gurrera et al. (2005) (Partial Least Squares).
**$p<0.01$.
*$p<0.05$.
[a] The association remains significant after statistical control for age.
[b] The association is no more significant after statistical control for age.

Gurrera et al., 2005; Portin et al., 2000). Shorter latency also predicted better digit span performance in most studies (Egan et al., 1994; Gurrera et al., 2005; O'Donnell et al., 1992; Polich et al., 1983; Stige et al., 2007; Walhovd and Fjell, 2001,2002) providing indirect support for the context-updating theory linking the P3b to working memory.

P3b amplitude has been related to performance on attention tasks, with larger amplitude associated with shorter completion time (Gurrera et al., 2005) and fewer errors (Portin et al., 2000). These findings are consistent with the view that P3b amplitude is influenced by the magnitude of attentional resources allocated to the task (Johnson, 1986; Kok, 1997). By contrast, the association between P3b amplitude and memory is less clear. In word-detection paradigms, studies have reported that words that elicit larger P3b amplitudes are better recalled in delayed recall trials than words eliciting smaller P3b amplitudes when participants use simple mnemonic strategies (Fabiani et al., 1986; Karis et al., 1984). These results were not supported by studies examining offline associations between P3b amplitude generated during an oddball task and performance on episodic memory tasks (Egan et al., 1994; Portin et al., 2000) although these studies did not control for the mnemonic strategies employed during the tasks.

In accordance with the theories relating to P3b function, P3b parameters tend not to be related to higher-level cognitive function. No association between P3b and performance on tasks requiring visuo-spatial perceptual reasoning was found by four different research