Individual Differences in Spatial Working Memory during Infancy: Contributions from EEG, ECG, and Temperament

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Introduction

Individual differences in cognitive performance during infancy have been attributed to multiple sources. The purpose of this study was to investigate three specific sources of individual differences in performance on an infant spatial working memory task: brain electrical activity (EEG coherence), cardiac activity (heart period), and temperament.

Methodology

Fifty healthy, full-term 8-month-old infants were recruited and 43 contributed complete EEG (coherence), ECG (heart period), working memory, and parent-report of temperament (Rothbart's IBQ) data. Working memory performance was assessed on a looking version of the A-not-B task (Bell, 2001; Bell & Wolfe, 2004). EEG and ECG were recorded during baseline and during working memory task performance.

WM Performance Groups

K-means cluster analysis was used to group infants based on their percentage correct responses on the same-side trials and their percentage correct responses on reversal trials of the A-not-B task. Diamond has speculated that reversal trials may require not only working memory skills, but also inhibitory control (Diamond et al., 1997). Thus, same-side and reversal trials were entered into the K-means analysis, as opposed to combining both trial types and creating above-the-mean and below-the-mean groups.

	same-side trials correct	reversal trials correct
High WM group (n=13)	59%	64%
Low WM group (n=30)	38%	7%

WM Performance Groups & Temperament

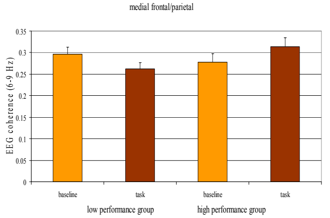
Working Memory Performance Group Differences on IBQ Temperament Scales

	High WM (n=13)	Low WM (n=30)	F	p	η_p^2
Activity Level	5.10 (.16)	4.50 (.14)	6.15	.017	.13
Distress to Limitations	3.81 (.18)	3.28 (.12)	5.90	.020	.13
Latency to Approach	3.11 (.21)	2.90 (.12)	.83	ns	.02
Duration of Orienting	3.77 (.27)	3.30 (.16)	2.51	ns	.06
Smiling and Laughter	5.20 (.25)	4.86 (.10)	2.18	ns	.05
Soothability	5.11 (.24)	4.77 (.15)	1.43	ns	.03

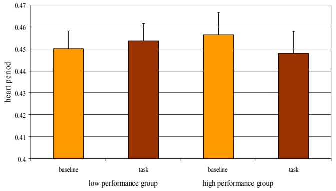
Note. For each ANOVA the degrees of freedom were (1,41).

WM Groups & EEG, ECG

The high WM group increased frontal/parietal coherence from baseline to task, whereas the low WM group decreased coherence,. Increases in coherence are indicative of increased connectivity and communication during task performance (Thatcher, 1994). Frontal/parietal interactions during spatial working memory tasks are common in the cognitive neuroscience literature (Bell, 2001; Nelson et al., 2000).



Hotelling's T^2=.30, $F(1,41)$=12.35, p=.001, η_p^2 =.23



Hotelling's T^2=.11, $F(1,41)$=3.79, p=.058, η_p^2 =.09

The high WM group exhibited a decrease in heart period (i.e., an increase in heart rate) from baseline to task. This pattern of heart period responses occurs during a stressor, such as a challenging mental task (Manuck, Kasprowicz, & Muldoon, 1990; Wolfe & Bell, 2004).

Predicting WM Performance Group

Results of Discriminant Function Analyses Predicting WM Performance Group

Analysis	Variables	Canonical Corr.	Wilks' λ	df	p
1	task F3-P3 EEG task F4-P4 EEG task heart period	.377	.858	3	.109
2	task F3-P3 EEG task F4-P4 EEG task heart period IBQ activity level IBQ distress to limitations	.511	.738	5	.040
3	F3-P3 EEG change F4-P4 EEG change heart period change	.637	.594	3	<.001
4	F3-P3 EEG change F4-P4 EEG change heart period change IBQ activity level IBQ distress to limitations	.726	.473	5	<.001

Note. "F3-P3 EEG change" refers to the difference between baseline and task F3-P3 EEG.

Predicting WM Performance Group (cont'd)

Classification Results for Discriminant Function Analyses

Analysis	Original Count	Predicted Group Membership: High WM	Predicted Group Membership: Low WM	Total
1*	n/a	n/a	n/a	n/a
2**	High WM	8 (61.5%)	5 (38.5%)	13
	Low WM	9 (30%)	21 (70%)	30
3***	High WM	12 (92.3%)	1 (7.7%)	13
	Low WM	7 (23.3%)	23 (76.7%)	30
4****	High WM	12 (92.3%)	1 (7.7%)	13
	Low WM	4 (13.3%)	26 (86.7%)	30

Notes. * Canonical correlation was not significant.
** Correct classification = 67.4%.
*** Correct classification = 81.4%.
**** Correct classification = 88.4%.

Discussion

There is much speculation in the infant literature that some relation exists between temperament and cognitive processing (Fox, 1994; Ruff & Rothbart, 1996). The brain/behavior system that has the capacity to tie together these cognitive and temperament processes is Posner's construct of the Anterior Attention System (Bush, Luu, & Posner, 2000), which begins to show some developmental changes in the second half of the first postnatal year (Rothbart, Derryberry, & Posner, 1994). This attentional system focuses on emotion (i.e., temperament)-attention and cognitive-attention functions of the anterior cingulate gyrus, which has many projections to the frontal cortex. The three sources of individual differences used in this study (frontal/parietal EEG, ECG heart period, and temperament) can all be related to the Anterior Attention System.

Maternal report measures of temperament linked augmented cognitive performance with increased distress and activity levels. This counterintuitive finding means that infants with high distress to limitations and activity levels may require more parental interactions than infants with lower distress and activity levels. Perhaps these infants require more parental support in the development of their attentional skills, a result that may lead to enhanced cognitive skills as infants develop.

These data give further support to the infant spatial working memory task as a valid indicator of individual differences in early cognitive processing and lay the foundation for future studies exploring the sources of these individual differences.

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