The Central Role of 2-Year-Old Inhibitory Control: Relations among Cognition, Emotion, and Brain-Electrical Activity

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This research was supported by NIH Grant HD043057

INTRODUCTION

Individual differences in toddler inhibitory control mechanisms have been the focus of much recent temperament research. The emergence of these early regulatory processes may have implications for cognitive and emotional development as well. The goal of this study was to examine the regulatory effects of inhibitory control associated with cognition, emotion, and electrophysiology during toddlerhood within a biologically-based framework of early childhood temperament.

The general hypothesis was that individual differences in inhibitory control are related to several dimensions of cognitive development (including working memory performance and language development), emotional development (including laboratory measures of effortful control), and electrophysiology (baseline-to-task EEG changes during toddler WM tasks), specifically, task-related increases in frontal lobe activity.

PARTICIPANTS

Participants in this study were 80 2-year-old toddlers (24-26 months) who had previously been recruited for an ongoing longitudinal investigation spanning infancy and early childhood, and examining individual differences in cognitive and emotional development. As infants, these children were recruited from the New River Valley area of southwest Virginia. Infants were recruited if they were born within 2 weeks of their expected due dates and experienced no prenatal or birth complications. At birth, all infants weighed at least 2,500 grams, required no oxygen at birth, and had no neurological diagnoses.

PROCEDURES

Cognitive Constructs

Toddler Working Memory- Upon arrival to the research lab, Polaroid photos were taken separately of the child and his/her mother. Toddlers were instructed to say their own name when shown their mother's picture, and to say "Mommy" when shown their own photo. Thus, this task required toddlers to remember 2 naming rules and inhibit a dominant response (correctly labeling the photos). Performance was scale-scored based on engagement in the task and extent of correctly-labeled reversals (Bell & Morasch, 2007).

Invisible Displacement- Toddlers watched as an attractive item (a red bouncy ball) was hidden at a central location and then shifted to one side of the testing table. During a 5-second standard delay and behind an opaque barrier, a second hiding location was provided. Performance on the task was calculated based on the proportion of correct searches (Diamond et al., 1997).

Language Assessment (MCDI)- The MacArthur Communicative Development Inventory (16-30 months) was used to assess vocabulary and grammar development within the sample. Scores derived from this assessment included Total Vocabulary and Total Grammar.

Emotion Constructs

Effortful Control (lab-based)- A 1-minute crayon delay task was used to assess behavioral effortful control. Toddlers were asked not to touch an attractive box of crayons until the experimenter returned to the room. Performance was calculated as the latency to touch the box of crayons after the experimenter exited the room (Vaughn et al., 1984).

Toddler Temperament (ECBQ)- The Early Childhood Behavior Questionnaire was used to assess maternal report of several dimensions of toddler temperament including inhibitory control (Putnam et al., 2006).

Electrode Acceptance- Assessment of whether or not children accepted the physiological electrodes (EEG cap) during the visit (0= refused cap, 1= cap was accepted and later refused, 2= cap accepted throughout the visit)

Physiological Constructs

Continuous EEG (6-9Hz)- EEG change scores were calculated by subtracting power values during baseline from those collected during the WM tasks. Whereas positive change scores indicated cortical activation, negative change scores indicated cortical deactivation at each scalp site. This is the typical pattern for infant and young child EEG activation during working memory tasks (Bell, 2001, 2002; Wolfe & Bell, 2004).

RESULTS

Analyses focused on the relations between maternal report of inhibitory control (ECBQ scale) with several other dimensions.

Cognitive Constructs. Inhibitory control was correlated with cognitive measures including WM (defined by Toddler WM performance, $r=.32$, $p=.01$). Toddlers with higher ratings of inhibitory control were better able to correctly remember two rules and inhibit a dominant response. In addition, inhibitory control was correlated with two measures of language development, total vocabulary and grammar score (r's = .41-.52, p's <.006). Toddlers with better inhibitory control had quantitatively (larger total vocabulary) and qualitatively (more complex phrasing) better language skills. However, invisible displacement performance was not associated with inhibitory control ($r=.19$, $p=.12$)

Emotion Constructs. Laboratory measures of effortful control were also related to maternal report of inhibitory control (crayon delay, $r=.29$, $p=.01$; electrode acceptance, $r=.24$, $p=.03$). Children with better inhibitory control were more likely to wait, as instructed, before touching the crayons. They were also more likely to accept the electrophysiological electrodes and keep them on throughout data collection.

Physiology Constructs. Finally, 2-year-old inhibitory control was associated with baseline-to-task increases (activation) in 6-9 Hz EEG power at frontal (Fp1 & Fp2), parietal (P4), and occipital (O1) locations (r's = .29-.37, p's <.05) during toddler WM tasks.

CONCLUSIONS

These data lend support to the idea that inhibitory control plays a central role in the organization and integration of cognition, emotion, and their neural correlates in toddlerhood. Future analyses will focus on individual differences in the developmental pathways leading to variability in inhibitory control mechanisms and the implications this may have on cognitive and emotional outcomes.