Early Behavioral Inhibition and Increased Error Monitoring Predict Later Social Phobia Symptoms in Childhood

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Objective: Behavioral inhibition (BI) is an early childhood temperament characterized by fearful responses to novelty and avoidance of social interactions. During adolescence, a subset of children with stable childhood BI develop social anxiety disorder and concurrently exhibit increased error monitoring. The current study examines whether increased error monitoring in 7-year-old, behaviorally inhibited children prospectively predicts risk for symptoms of social phobia at age 9 years. **Method:** A total of 291 children were characterized on BI at 24 and 36 months of age. Children were seen again at 7 years of age, when they performed a Flanker task, and event-related potential (ERP) indices of response monitoring were generated. At age 9, self- and maternal-report of social phobia symptoms were obtained. **Results:** Children high in BI, compared to those low in BI, displayed increased error monitoring at age 7, as indexed by larger (i.e., more negative) error-related negativity (ERN) amplitudes. In addition, early BI was related to later childhood social phobia symptoms at age 9 among children with a large difference in amplitude between ERN and correct-response negativity (CRN) at age 7. **Conclusions:** Heightened error monitoring predicts risk for later social phobia symptoms in children with high BI. Research assessing response monitoring in children with BI may refine our understanding of the mechanisms underlying risk for later anxiety disorders and inform prevention efforts. J. Am. Acad. Child Adolesc. Psychiatry, 2014;53(4):447–455. **Key Words:** behavioral inhibition, error monitoring, error-related negativity (ERN), anxiety, longitudinal

Behavioral inhibition (BI) is an early childhood temperament characterized by fearful responses to novelty and avoidance of social interactions.[1-4] Adolescents characterized with BI in childhood face increased risk for anxiety,[1,5-7] particularly social phobia.[8] Nevertheless, only about 40% of children with BI develop anxiety.[8] Behaviorally inhibited children who show enhanced vigilance face particularly high risk for anxiety,[9] possibly through increased response monitoring.[10] Thus, neural correlates associated with this underlying mechanism may identify a subset of behaviorally inhibited children at particularly high risk.[1] Prior studies collected data concurrently rather than prospectively in adolescence or adulthood.[1,11-13] The current prospective study examines response-monitoring data at age 7 to predict anxiety at age 9, in order to understand why some, but not all, behaviorally inhibited children develop anxiety.

Event-related potentials (ERPs) associated with response monitoring have been linked to anxiety.[11-16] These include the error-related negativity (ERN), correct response negativity (CRN), and error positivity (Pe). The ERN has a medial–frontal scalp distribution, typically peaking 50 to 100 ms after an erroneous response.[17] Developmental studies suggest that this component is expressed in an earlier time window and with smaller amplitude in young children than in adolescents and adults.[18] Furthermore, the ERN often precedes an erroneous response, potentially occurring precisely when errors are initiated.[19] In contrast, the CRN occurs after correct responses and is considered an index of response control.[20] Trials following this component are characterized by increased accuracy and reduced reaction time interference.[21] Furthermore, the CRN reflects a comparison between the actual response and desired response[22] and is frequently used as a

comparison condition to the ERN (ERN–CRN).[23-25] The Pe is also associated with response monitoring, and is usually observed between 200 and 500 milliseconds after an error, and its functional significance has been debated.[26] Some consider it to reflect conscious awareness of errors,[27] whereas others argue that it is associated with affective processing[22] or the motivational significance of the error.[28]

Studies on response monitoring and anxiety consistently find increased ERNs in adults with anxiety relative to healthy adults.[12,13,15,16] Similar findings emerge in children and adolescents.[14,29,30] For example, anxious 6-year-olds were characterized by a larger (i.e., more negative) ERN.[31] In addition, among older children (aged 11–13 years), elevated anxiety symptoms were associated with a larger ERN, whereas among younger children (aged 8–10 years), the ERN–anxiety relation was not significant.[11] Furthermore, a smaller Pe was associated with greater anxiety, but only among older children.[11] Thus, although the ERN is linked to anxiety, developmental questions remain that can be clarified through a longitudinal study of BI.

In prior research, adolescents high in childhood BI displayed increased ERNs compared to those with low childhood BI, linking early BI to increased error monitoring in adolescence. Importantly, only among adolescents with a history of childhood BI did larger ERN amplitudes relate to higher levels of anxiety.[1] This prior study assessed ERN in adolescence concurrently with anxiety. As a result, it is unclear whether error monitoring moderates the link between early BI and later anxiety, and whether this pattern is present earlier in development, before the onset of anxiety.

The present longitudinal study examined response monitoring among 7-year-old children, characterized by BI during early childhood. We focused on social phobia symptoms, the most common class of anxiety linked to BI.[5,7,8,32,33] We expected increased error monitoring in high, relative to low, behaviorally inhibited children. Furthermore, we expected that error monitoring would moderate the link between early BI and later social phobia symptoms during childhood.

METHOD

Participants and Procedure

Infants (N = 779) were seen at 4 months of age, during which positive and negative affect and motor reactivity to novel stimuli were assessed (a complete description is provided by Hane *et al.*[34]). Of this sample, 291 infants (135 male and 156 female) representing the full range of reactivity were selected for a longitudinal study, with 64% white, 14% African American, and 22% from other backgrounds. When children were 24 and 36 months of age, observations were conducted on 268 participants, and maternal-report of temperament was collected. At age 7, a total of 173 children completed an ERP Flanker task.[35] Reasons for missing data included difficulty scheduling visits (n = 87), refusal to wear the electroencephalography (EEG) net or complete the task (n = 4), and technical errors (n = 4). An additional 47 children were excluded because they completed a version of the task that did not yield enough errors. Of the 126 who completed the task, children with less than 30% accuracy or fewer than 10 artifact-free trials were excluded, yielding behavioral data on 113 participants, CRN data on 106 participants, and ERN, ERN–CRN, and Pe data on 67 participants. No significant differences were found on BI (all p values >.09) or gender (all p values >.22), for participants who were included or excluded. At age 7 years, we obtained maternal-report on the Child Behavior Checklist (CBCL; n = 188).[36] Participants were re-assessed at 9 years using maternal- and child-report on the Screen for Child Anxiety Related Emotional Disorders–Revised (SCARED-R) (n = 125),[37,38] and the Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime Version (K-SADS-PL)[39] (n = 116). Hierarchical regression examined ERP moderation of the BI-social phobia symptoms relations in 67 (CRN), 46 (ERN–CRN), or 47 (ERN, Pe) participants. Consent was obtained in an institutional review board–approved protocol.

Measures

Behavioral Inhibition. BI was observed at 24 and 36 months of age during 3 episodes (stranger, robot, tunnel) involving unfamiliar persons and objects.[2,40] Observations were coded for each episode, and interrater reliability (intraclass correlations) ranged from 0.72 to 0.98 (mean = 0.87; 19% overlap; 2 coders) for 2-year coding and from 0.93 to 1.00 (mean = 0.98; 10% overlap; 2 coders) for 3-year coding. Maternal-report of social fear was obtained using the Toddler Behavior Assessment Questionnaire (TBAQ).[41] As in previous work, measures were standardized and averaged to create a BI composite.[42,43] Combining data from different contexts, informants, and ages better reflects the child's temperament than 1 single measure alone. The BI composite was created based on theory and confirmed through principal components analysis (eigenvalue = 2.04; loadings = 0.62–0.81).

Flanker Task. The Flanker task was administered at 7 years of age.[35] Participants completed 24 practice trials. For 4 errors or less, they completed a faster version of the task; for 5 to 11 errors, they completed a slower version; for 12 to 24 errors, they repeated the practice until they had 11 errors or less. A total of 11