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The Stony Brook Temperament Study: Early Antecedents and Pathways to Emotional Disorders

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Abstract

In this article, we summarize findings from the Stony Brook Temperament Study, which seeks to elucidate the early antecedents and pathways to later depressive and anxiety disorders. The study focuses on parents' internalizing disorders and children's early temperament as distal risk factors that operate, in part, through biobehavioral reward and threat systems. We summarize findings linking parents' emotional disorders and observations of children's early temperament to subsequent neural measures of children's affective processing. Next, we review findings showing that children's temperament and affective processing predict subsequent depression and anxiety. We also show that many of these associations are moderated by environmental factors, such as parenting and stress. Finally, we relate our findings to literature on the relationships of early temperament and affective processing to anxiety and depression in youth.

Keywords

temperament; affective processing; risk; depression; anxiety; children

Depressive disorders are prevalent and impairing, are often chronic or intermittent, and can persist throughout life. Although age of onset varies, these disorders peak in adolescence and early adulthood. Depressive disorders are often accompanied or preceded by anxiety disorders, which are also highly prevalent, impairing, and persistent, and typically begin in childhood or adolescence (1).

Depression and anxiety are complex, multifactorial, developmental disorders that may be reached by different pathways and lead to different outcomes, and have both shared and unique liabilities (1). In this article, we report on the Stony Brook Temperament Study, which seeks to elucidate the antecedents and pathways to depressive disorders as well as anxiety disorders. The ongoing study examines a community sample of 609 children and their parents from early childhood through adolescence. Children were first assessed at age 3 and are reassessed at three-year intervals through adolescence, with several briefer assessments between major waves. Retention has been approximately 80% at each wave. We used an unselected sample because depression and anxiety are common and we did not want to bias the distribution of risk factors via our sampling frame. We started in early childhood

to minimize the likelihood that children would already have depressive disorders, and because by age 3, behavior can predict later depression (2).

In our work, we were guided by theory and research on biobehavioral motivational systems, particularly the appetitive/approach/behavioral activation and defensive/withdrawal/behavioral inhibition systems that have been implicated in emotional disorders (3–5). These systems are similar to the positive and negative valence systems in the Research Domain Criteria (RDoC; 6). The literature on children's temperament (7, 8) provided conceptual and assessment tools to examine early expressions of these systems in the form of temperamental positive and negative emotionality at a developmental period when self-report and neural measures are not feasible. As the children in our study matured, we have increasingly emphasized neural measures of positive and negative valence system functioning because these systems are more viable and comparable behavioral measures are lacking in older children.

According to our heuristic model (Figure 1), parents' internalizing disorders and children's temperament serve as distal risk factors for depression and anxiety (8–10). We also suggest that these distal risk factors are correlated modestly due to the heterogeneity of parents' depression and anxiety, and because part of the risk conveyed by parents' psychopathology operates through the positive and negative valence systems. In addition, we assume that emotional disorders vary along a continuum of severity and often first appear in the form of subclinical symptoms. Hence, risk due to parents' psychopathology and dysregulation of children's positive and negative valence systems may be expressed initially in the form of subclinical symptoms (e.g., depression, anxiety, irritability) that later escalate to full-fledged depressive and anxiety disorders (11). Finally, we hypothesize that dysregulation of the positive and negative valence systems and the development of depressive and anxiety symptoms and disorders are moderated by contextual factors (e.g., parenting, life stressors) and development in puberty.

In the following three sections, we summarize early findings regarding portions of our model. We recently completed the age 12 wave and are beginning to analyze these data, so we focus on our findings on early through late childhood. First, we review results linking parents' emotional disorders to neural measures of affective processing in children. Next, we discuss findings linking observations of children's early temperament to later affective processing. Finally, we summarize studies linking early temperament and affective processing with subsequent anxiety and depression.

Parents' Emotional Disorders

Parents' psychopathology was assessed using semistructured diagnostic interviews. Consistent with epidemiological studies of adults of similar ages, lifetime rates of depression and anxiety disorders were 32%–34% in mothers and 17%–19% in fathers (see 10). Also consistent with the literature, we have typically observed stronger effects on children for maternal psychopathology than for paternal psychopathology (12), although it is unclear whether this reflects the greater involvement of mothers in childrearing or sex-specific genetic influences (13).

Consistent with the heuristic model in Figure 1, our findings suggest that children of depressed mothers exhibit diminished reactivity to emotional stimuli in general, and reduced positive valence system activity, both at rest and in response to reward in particular. In the first two waves, we used electroencephalography (EEG) while children were at rest to assess hemispheric asymmetry in the alpha band over the frontal region of the cortex as a measure of activity in the positive (approach) valence system. Davidson (3) hypothesized that depression is associated with diminished approach sensitivity, as indicated by reduced alpha activity in the left, relative to the right, frontal region on EEG (see 14 for a meta-analysis of this literature). In our study, young children of mothers with a history of depression exhibited the hypothesized frontal asymmetry. This was qualified by development in that it was not evident until children were 6 years old; as preschoolers, children of mothers with and without a history of depression did not differ (15). It is unclear whether these findings reflect developmental constraints on the expression of heritable risk or the cumulative effects of environmental influences. Regardless, they indicate that vulnerability factors may emerge at different stages of development so findings vary depending on children's age. They also highlight the importance of developmentally informed studies to determine when putative risk biomarkers are most predictive.

When the children were 6, we also assessed their electrocortical reactivity to emotionally valenced faces, focusing on the late positive potential component, which reflects selective attention to motivationally salient information. Children of depressed mothers exhibited diminished late positive potentials to both positive and negative, relative to neutral, faces (16). This suggests that children of depressed parents exhibit diminished neural reactivity to emotional stimuli regardless of valence, and is consistent with evidence that depression is associated with a general emotional disengagement with the environment (17). In addition, it supports findings (15) indicating that children of depressed mothers can be distinguished from their peers based on electrocortical activity as early as age 6.

When the children were 9, we examined their sensitivity to reward by recording event-related potentials (ERPs) in a task that involved choosing between two doors, one of which led to winning a small amount of money and the other to losing a small amount. The reward positivity is indexed by the neural response elicited by gains relative to losses. A history of maternal depression, when it was at least moderately severe, and a history of maternal depression of any severity in the absence of a history of anxiety, were associated with a significantly blunted reward positivity in children (18). In addition, the link between parents' depression and children's processing of rewards was moderated by parenting. Blunted reward sensitivity was limited to children of depressed parents who also were frequently nonsupportive in their parenting, suggesting the importance of contextual factors in moderating the effects of familial risk (19).

While parents' depression (but not anxiety) is apparently associated with blunted sensitivity to reward and pleasant stimuli, parents' anxiety is related to enhanced startle reactivity in children. At age 9, children viewed positively, neutral, or negatively valenced pictures before being exposed to an unpredictable loud noise. Aversive stimuli typically elicit startle responses, as indicated by contraction of the eye muscles, and the magnitude of this response is believed to reflect defensive/negative valence system sensitivity (5). However,

the magnitude of startle responses is modulated by participants' prior affective states, with startle being smaller following positively valenced stimuli and larger following negatively valenced stimuli. In a study by Kujawa and colleagues (20), parents' history of anxiety disorder predicted significantly greater startle responses in children after they saw unpleasant pictures and less attenuated startle responses after they saw pleasant pictures. In contrast, parents' history of depressive disorders was unrelated to the magnitude of the startle response. Thus, despite evidence of overlapping genetic influences in depression and anxiety (1), psychophysiological measures apparently can distinguish children at risk for these two groups of disorders.

Temperamental Emotionality

Our model suggests that early childhood temperament also relates to processing of reward/pleasant and threat/unpleasant stimuli. Our preschool assessments of temperament focused on assessing behavioral expressions of positive emotionality (including positive affect/exuberance and interest/engagement) and negative emotionality (including sadness, fearfulness, and anger) using the Laboratory Temperament Battery (7). We emphasized observational measures of children's temperamental emotionality to circumvent biases in parents' reports of their children's temperament (21). In line with our model, observations of early temperament were theoretically consistent with subsequent ERP measures of the positive and negative valence systems. For example, lower positive emotionality at age 3 predicted diminished reward positivity amplitudes at age 9 (22). In our examination of children's reactivity to pleasant and unpleasant pictures, lower observed positive emotionality predicted reduced late positive potential amplitudes to pleasant, but not unpleasant, images at age 9. While negative emotionality as an overall composite was not related to the late positive potential, early fearfulness predicted an enhanced response to unpleasant images, whereas early sadness predicted a diminished response to unpleasant images (23).

We also examined the association between observations of negative emotionality at age 3 and neural reactivity to emotional and neutral faces and to houses at age 11 using functional magnetic resonance imaging (fMRI); the house condition was included to distinguish faces from objects. We found that higher negative emotionality in early childhood was associated with significantly greater activations in the left amygdala and left fusiform face area during emotional and neutral face conditions relative to the house condition, and with lower functional connectivity between these two regions during the face conditions (24). Thus, observations of children's emotional reactivity as early as age 3 apparently predict their neural reactivity to emotionally relevant stimuli in late childhood.

Links to Later Depression and Anxiety

The children we are studying are just beginning to enter the risk period for depressive disorders, so few have developed depression yet.¹ However, we have examined early

¹Using a semistructured diagnostic interview, six participants (1.2% of the sample) met criteria from the *Diagnostic and Statistical Manual of Mental Disorders* (25) for a lifetime major depressive or dysthymic disorder by age 9.

predictors of the onset of anxiety disorders, as well as increases in anxiety and depressive symptoms.

Experts have long hypothesized that temperament is a vulnerability factor (or diathesis) that predisposes individuals to emotional problems under stress (8). We tested this idea after Hurricane Sandy hit Long Island, damaging 100,000 homes and leaving 4.4 million cubic yards of debris. The hurricane occurred a year after our participants completed the age 9 assessment. Immediately after the disaster, we asked mothers to complete questionnaires concerning hurricane-related stressors (e.g., property damage, prolonged loss of electrical power) and their children's symptoms. Observed negative emotionality at age 3 interacted with hurricane-related stress to predict increases in internalizing symptoms relative to the age 9 assessment. Moreover, the nature of the interaction depended on the specific component (or facet) of negative emotionality. Thus, after the disaster, children with greater temperamental sadness at age 3 who experienced high levels of stress related to Hurricane Sandy had significantly more symptoms of depression, and children with greater temperamental fearfulness at age 3 who experienced high levels of hurricane-related stress had significantly more anxiety symptoms (26). These results are consistent with data (23) on the late positive potential described earlier in highlighting the importance of finer-grained examination of the facets of negative emotionality for understanding the development of specific forms of internalizing psychopathology (8).

Our findings are consistent with studies reporting that early temperamental fearfulness (or behavioral inhibition) is a risk factor for later anxiety (27). However, most fearful/behaviorally inhibited children do not develop anxiety disorders, so it is important to identify moderators of this relationship. In addition to these findings for life stress, we recently found that the link between temperamental fearfulness at age 3 and the subsequent development of anxiety disorders is moderated by parents' own histories of temperamental fearfulness in childhood. Fearful children of parents who were fearful as children are most likely to develop anxiety disorders by age 9 (28). While the processes underlying this finding need to be elucidated, parents with a history of temperamental fearfulness may use parenting practices, such as being overprotective or modeling avoidant behavior, that increase susceptibility to anxiety in temperamentally vulnerable children (29). Alternatively, parents' temperamental fearfulness may be a marker for a more genetic or severe subtype associated with greater vulnerability. Regardless, our data indicate that once children have developed an anxiety disorder, early temperamental fearfulness predicts a more persistent course of anxiety (30). Taken together, these findings emphasize the importance of early intervention in children with temperamental and familial vulnerabilities.

We also examined whether early neural indices of affective processing predict later internalizing symptoms and disorders. For example, when children were 6, we assessed their error-related brain activity by recording EEG on a speeded response task (go/no go). In adults and older youth, anxiety-related traits and symptoms are associated with increased amplitudes on the error-related negativity component of the ERP (31). In one of the first demonstrations of a predictive biomarker for anxiety, increased error-related negativity at age 6 predicted the subsequent first onset of anxiety disorder by age 9 (32). Moreover, error-related neural activity at age 6 was influenced by prior harsh maternal parenting, assessed at

age 3, and mediated the relationship between early parenting and later anxiety disorder (33). This raises the possibility that interventions targeting harsh parenting may alter error-related neural activity, which in turn could reduce children's risk for developing anxiety disorders.

Moreover, if abnormalities in neural indices of affective processing are expressions of underlying vulnerabilities, then children with these tendencies might develop symptoms after experiencing high levels of stress. In our study of children who had experienced Hurricane Sandy, exposure to hurricane-related stressors moderated the association between neural reactivity before the hurricane to emotionally valenced pictures and change in psychological symptoms. Children with smaller late positive potential amplitudes to pleasant images and greater amplitudes to unpleasant images in the age 9 assessment who were exposed to higher levels of hurricane-related stressors had the greatest increases in internalizing symptoms after the hurricane (34).

Conclusions

A major goal of the Stony Brook Temperament Study is to trace the pathways from parents' emotional disorders and early behavioral manifestations of positive and negative valence systems through neural indices of processing emotional information to the development of depressive and anxiety symptoms and disorders, while considering the moderating influences of parenting and life stress (Figure 1). Consistent with a growing literature, primarily with older youth (35), maternal depression was associated with blunted neural processing of positive and negative stimuli in children. Moreover, these abnormalities were apparently evident as early as age 6. In addition, these associations were moderated by parenting. In contrast, parents' anxiety disorders were associated with a heightened startle response to emotional stimuli in children. These findings suggest that there appears to be a large window for early intervention between observable risk markers and the peak period of incidence; they also suggest targets for intervention.

Although it is widely assumed that temperamental dispositions are associated with neural reactivity to and processing of emotional stimuli, the literature on this is limited and based largely on adults (36). The exception is studies examining links between temperamental fearfulness and neural responses to threat and reward (e.g., 37, 38). Consistent with this research, and with the RDoC perspective that positive and negative valence system functioning can be observed across many levels of analysis, early temperamental positive emotionality, sadness, and fearfulness were associated with theoretically consistent patterns of neural reactivity to rewarding, pleasant, unpleasant, and threatening stimuli using resting EEG, ERPs, and fMRI reactivity and connectivity. Moreover, these associations were seen across significant periods of development, posing a particularly strong test.

Additionally, as the children in our studies approach the period of heightened risk for emotional disorders (1), we are beginning to see that early behavioral and neural measures related to the positive and negative valence systems predict subsequent increases in depressive and anxiety symptoms and onsets of anxiety disorders. These findings add to a growing number of prospective studies, largely in older youth, showing that personality traits and neural reactivity to emotional stimuli predict subsequent emotional disorders (e.g.,

39, 40). Furthermore, our findings extend the few studies showing that, consistent with diathesis-stress models, life stressors moderate associations of early temperamental and neural vulnerabilities with subsequent internalizing psychopathology (41, 42). Finally, our data suggest the importance of considering risk factors at many levels simultaneously because temperamental and neural diatheses can combine to create potent vulnerabilities to internalizing symptoms in the face of major stressors (38, 43).

Research in this area needs to address many issues. First, it is critical to identify predictors of the first onsets of depressive and anxiety disorders in adolescence, and determine whether the effects of early temperament and neural indices of emotion processing, as well as the moderating effects of early parenting and stress, are sustained over time. Second, it is important to explore the effects of potential moderators associated with the emerging developmental challenges of adolescence (e.g., puberty), the reorganization and increased salience of peer relationships, and the emergence of romantic relationships (44). Furthermore, while family relationships often change in adolescence, they remain a source of support and stress, and researchers need to explore how they moderate the emergence of psychopathology in this period.

Third, researchers should map the developmental trajectories of positive and negative valence system functioning, such as the expected increase in reward sensitivity in midadolescence (44). In particular, it is important to trace the many paths from positive and negative valence system functioning to emotional disorders, and identify points in development when risk factors provide maximum leverage in predicting psychopathology. Key questions include whether low positive valence system sensitivity can explain the heterotypic continuity of early temperamental fearfulness and anxiety disorders with the onset of depression in adolescence, and whether biobehavioral indicators of regulatory functioning can explain why some young children with elevated levels of irritability subsequently develop internalizing symptoms while others develop externalizing problems (45).

Long-term longitudinal studies offer the most effective way to understand the development of psychopathology and provide a perspective that cross-sectional designs lack. However, such studies also raise questions and challenges. For example, our findings suggesting that risk factors are evident in early childhood highlight the importance of starting longitudinal studies in infancy or even in utero. However, developing appropriate behavioral and neural measures will be challenging. In particular, we need to develop measures that are age appropriate and can be repeated across developmental stages, and to refine analytic strategies that can equate age-specific measures to examine trajectories over time.

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Note: Bolded arrows refer to moderation

Figure 1.
Heuristic model of pathways of risk for depression and anxiety disorders.