

Neural Reactivity to Emotional Stimuli Prospectively Predicts the Impact of a Natural Disaster on Psychiatric Symptoms in Children

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ABSTRACT

BACKGROUND: Natural disasters expose entire communities to stress and trauma, leading to increased risk for psychiatric symptoms. Yet, the majority of exposed individuals are resilient, highlighting the importance of identifying underlying factors that contribute to outcomes.

METHODS: The current study was part of a larger prospective study of children in Long Island, New York ($n = 260$). At age 9, children viewed unpleasant and pleasant images while the late positive potential (LPP), an event-related potential component that reflects sustained attention toward salient information, was measured. Following the event-related potential assessment, Hurricane Sandy, the second costliest hurricane in United States history, hit the region. Eight weeks after the hurricane, mothers reported on exposure to hurricane-related stress and children's internalizing and externalizing symptoms. Symptoms were reassessed 8 months after the hurricane.

RESULTS: The LPP predicted both internalizing and externalizing symptoms after accounting for prehurricane symptomatology and interacted with stress to predict externalizing symptoms. Among children exposed to higher levels of hurricane-related stress, enhanced neural reactivity to unpleasant images predicted greater externalizing symptoms 8 weeks after the disaster, while greater neural reactivity to pleasant images predicted lower externalizing symptoms. Moreover, interactions between the LPP and stress continued to predict externalizing symptoms 8 months after the hurricane.

CONCLUSIONS: Results indicate that heightened neural reactivity and attention toward unpleasant information, as measured by the LPP, predispose children to psychiatric symptoms when exposed to higher levels of stress related to natural disasters, while greater reactivity to and processing of pleasant information may be a protective factor.

Keywords: Event-related potentials, Externalizing, Internalizing, Natural disaster, Stress, Vulnerability

<http://dx.doi.org/10.1016/j.biopsych.2015.09.008>

Exposure to stress in childhood and adolescence prospectively predicts increases in both internalizing and externalizing symptoms across development [for a review (1)]. At the same time, most children experience some level of stress and remain resilient; thus, identifying vulnerability factors that moderate the association between stress and the development of psychopathology is of paramount public health importance (2,3).

Natural disasters are one stressor linked to increased risk of both internalizing (e.g., posttraumatic stress, depression, anxiety) and externalizing symptoms (e.g., oppositional and aggressive behavior) that may persist for months or even years after the disaster (4–11). Individuals who experience a greater number of disaster-related stressors tend to exhibit higher levels of symptoms (10,12,13). Nonetheless, only a minority of those exposed to natural disasters will develop serious psychological symptoms (14).

Natural disasters are circumscribed in time and affect entire communities; thus, they are less likely than other stressors to

be confounded with pre-existing child and family characteristics. Examining children exposed to disasters can provide insights into neural mechanisms underlying risk and resilience (15,16). However, as disasters typically occur with little warning, it is often impossible to determine whether factors that moderate children's responses reflect vulnerabilities that predispose to symptoms or consequences of stress exposure.

Most studies have focused on psychosocial factors that influence reactivity to stress in youth experiencing natural disasters. For example, child temperament and symptoms of psychopathology before the disaster predict symptoms following the disaster (13,15,17,18). In addition, social influences contribute to responses to disasters: greater social support is a protective factor, whereas negative family dynamics predict poorer outcomes (11,18,19).

A few prospective functional magnetic resonance imaging (fMRI) studies have evaluated neural processes that predispose to developing symptoms in response to trauma, including war and terrorism (20,21) and general life stress (22) but

not natural disasters. The little existing evidence suggests that amygdala hyperreactivity to threat may contribute to risk (20–22). For example, in a small fMRI study of adolescents, greater amygdala reactivity to threatening images prospectively predicted increased posttraumatic stress symptoms after the Boston Marathon bombing (20). In addition, a large fMRI study of adults indicated that greater amygdala reactivity to threat interacted with stressful life events 1 to 4 years later to predict increased internalizing symptoms (22).

The late positive potential (LPP) is an event-related potential (ERP) component that provides a neural measure of emotional processing that can be reliably assessed across development (23). The LPP is a relative positivity in the ERP that begins as early as 200 ms after stimulus onset and is increased for emotional compared with neutral stimuli; this emotional modulation of the LPP is pronounced throughout the duration of picture presentation and reflects sustained attention toward motivationally salient information (24–26).

Abnormalities in the LPP are associated with internalizing disorders, such as anxiety and depression (27–33), as well as externalizing symptoms in both youth and adults (34,35). Cross-sectional research suggests the LPP may measure emotional processing styles that contribute to vulnerability for psychopathology. For example, offspring of parents with fear disorders (i.e., panic disorder, social anxiety disorder, and specific phobia) and children with fearful temperament showed enhanced LPPs to unpleasant stimuli (36,37). In addition, blunted LPPs to emotional stimuli have been observed in youth at risk for depression based on both parental history of depression and temperament style (37–39). Importantly, there is evidence that individual differences in processing and coping with emotions contribute to children's responses to stress (40), suggesting that the magnitude of the LPP may moderate effects of stress on the development of symptoms. However, no research has investigated whether neural processing of emotion, as measured by the LPP, prospectively predicts changes in symptoms in children, either alone or in conjunction with stress.

The current study examined neural reactivity to emotional images as a vulnerability for psychiatric symptoms following a natural disaster. Hurricane Sandy struck the Long Island, New York, region on October 29, 2012, destroying 100,000 homes, and is estimated to be the second costliest hurricane in United States history, after Hurricane Katrina (41). As part of a pre-existing study, a large sample of 9-year-old children completed an emotional processing task in which ERPs were recorded as participants viewed pleasant, neutral, and unpleasant images prior to the hurricane. In addition, mothers reported on child internalizing and externalizing symptoms. Approximately 8 weeks after Hurricane Sandy, participants' mothers completed a questionnaire assessing exposure to hurricane-related stressors and children's symptoms. To assess long-term impact, mothers completed questionnaires again approximately 8 months after the hurricane. We evaluated neural reactivity to emotional images (i.e., LPP) as a prospective predictor of symptoms after the hurricane, both as a main effect and as an interaction with hurricane-related stress. We hypothesized that an enhanced LPP to unpleasant images would predict a greater increase in symptoms and, consistent with vulnerability-stress models (3), that these effects

would be most apparent among children who experienced higher levels of stress. Additional exploratory analyses evaluated whether the LPP to pleasant images also predicted symptoms.

METHODS AND MATERIALS

Participants

Participants were 9- to 12-year-olds from a larger prospective community sample of children, initially recruited between 3 to 6 years old. All children living with at least one English-speaking biological parent and free of significant medical or developmental disabilities were eligible (42). A total of 323 children completed the emotional interrupt electroencephalogram (EEG) task and prehurricane symptom measures, were in the area at the time of Hurricane Sandy, and completed the 8-week posthurricane questionnaire. Of these participants, 63 were excluded for excessively noisy EEG data; fewer than 15 correct, artifact-free trials per condition; and/or poor accuracy (<65%) on the emotional interrupt task. The excluded sample had higher mother-reported internalizing ($t_{321} = 2.70, p = .01$; mean difference = 2.47) and externalizing symptoms ($t_{321} = 3.13, p < .01$; mean difference = 2.93) than the included sample before the hurricane, and the groups continued to differ on symptoms at the initial posthurricane assessment ($p < .05$) but did not significantly differ on hurricane-related stress ($p = .16$). The final sample included 260 children with a mean age of 9.16 (SD = .34) at the EEG assessment and 10.41 (SD = .78) at the 8-week posthurricane assessment. Participants were 45.8% female; 89.6% Caucasian, 6.9% African American, 3.1% Asian, and .4% Native American; 8.1% identified as Hispanic/Latino.

Procedure

Study protocols were approved by the Institutional Review Board at Stony Brook University. Informed consent was obtained from all parents and verbal assent was obtained from children. Participants and one parent visited the laboratory as close as possible to the child's ninth birthday to complete the EEG assessment and measures of the child's symptoms. Following the hurricane, mothers were asked to complete an online questionnaire to assess hurricane-related stressors and the child's symptoms. On average, these questionnaires were completed 8.52 weeks (SD = 1.55) following the hurricane and 53.58 weeks (SD = 31.69) after the EEG assessment. Seven months after the hurricane, mothers were again asked to report on current child symptoms. On average, this questionnaire was completed 7.69 months (SD = .81) after the hurricane (58 mothers did not complete the follow-up questionnaire, leaving data for 202 children).

Measures

Emotional Interrupt Task. Before the hurricane, participants completed a version of the emotional interrupt paradigm (43,44) previously used to measure the LPP in youth (37,45). Sixty developmentally appropriate pictures from the International Affective Picture System (46) were presented: 20 pleasant images (e.g., children playing, cute animals), 20 neutral images (e.g., people in neutral situations, household

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