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Childhood maltreatment and response to novel face stimuli presented during functional magnetic resonance imaging in adults

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ABSTRACT

Facial cues contain important information for guiding social interactions, but not all humans are equally expert at face processing. A number of factors, both genetic and environmental, contribute to differences in face-processing ability. For example, both heritable individual differences in temperament and exposure to childhood maltreatment are associated with alterations in face processing ability and social function. Understanding the neural correlates of alterations in face-processing ability can provide insights into how genetic and environmental risk factors impair social functioning. We examined the association between childhood maltreatment and blood-oxygenation-level-dependent (BOLD) signal as measured in functional magnetic resonance imaging (fMRI) in a group of young adults with an inhibited temperament. We hypothesized that childhood maltreatment exposure would correlate positively with BOLD signal in regions subserving face processing and novelty detection during viewing of novel compared to familiar faces. Functional magnetic resonance imaging (fMRI) degree of exposure to childhood maltreatment was positively correlated with BOLD signal in the bilateral fusiform gyri and the left hippocampus. These fMRI findings suggest that young adults with an inhibited temperament and a history of maltreatment may be particularly vulnerable to neural alterations. These differences could be related to a heightened sensitivity to potential threat—for example, from new people–and may contribute to both the altered social functioning and increased incidence of anxiety disorders in these individuals.

1. Introduction

The ability to interact with others and interpret social information is critical for humans. Facial cues are an important source of information used in social interactions. Consistent with the importance of understanding facial cues, face-processing skills emerge early in infancy (for review, see Gauthier and Nelson, 2001) and are refined throughout development. However, not all humans are equally expert at facial processing; variation in face-processing ability may be due to a variety of factors, including genetic and environmental factors. For example, inhibited (or shy) temperament is a heritable (Robinson et al., 1992) and biologically based trait (Kagan et al., 1987; Goldsmith and Lemery, 2000; Fox et al., 2005) that influences face-processing ability. Shy children make more errors in identifying faces (Brunet et al., 2010), and event-related potential studies both eye-tracking (Brunet et al., 2009) and ERP studies (Jetha et al., 2012) suggest altered sensitivity to emotional faces. Environmental insults, such as childhood maltreatment, also impact face processing. For example, adults who were maltreated as children show behavioral alterations in face processing, such as enhanced sensitivity to emotional faces, and attentional biases to threatening faces (Pollak et al., 2000; Pollak and Kistler, 2002; Gibb et al., 2009). Given that faces provide critical social cues, genetic or environmental factors that impact face processing may cause impairments in social functioning.

Identifying neural correlates of altered face processing can provide critical insights into pathophysiological risk factors related to impaired social functioning. Face processing is supported by a neural network composed of sensory regions – such as the fusiform face area (FFA) – and limbic regions – such as the amygdala and hippocampus. The FFA is a secondary visual cortical region that shows increased activation in response to viewing face stimuli (Grill-Spector et al., 2004). In humans, the FFA response to faces may represent its broader role in visual expertise (Gauthier and Tarr, 2002). In the

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medial temporal lobe, the amygdala and hippocampus are limbic regions critically involved in face processing. The amygdala is involved in processing of emotional faces (Fusar-Poli et al., 2009), modulation of face recognition (Gobbini and Haxby, 2007), and evaluation of potential threat, such as the trustworthiness of a face (Adolphs et al., 1998; Winston et al., 2002). The hippocampus modulates visual processing (Vuilleumier et al., 2004) by facilitating contextual interpretation of social stimuli such as faces, particularly face recognition and familiarity (Bengner and Malina, 2008).

Previous studies have shown that individuals with an inhibited temperament show alterations during face processing in the amygdala (Schwartz et al., 2003; Perez-Edgar et al., 2007; Blackford et al., 2011) and hippocampus (Blackford et al., in press). Given the behavioral effects of childhood maltreatment on face-processing ability one might also expect childhood maltreatment to be associated with neural differences during face processing; however, only a few studies have directly investigated this topic. Functional neuroimaging studies examining the neural correlates of trauma – either traumatic event histories or post-traumatic stress disorder (PTSD) – report altered amygdala activation to emotional stimuli in general (for review, see Lanius et al., 2006). When viewing threatening faces, adults with a history of childhood maltreatment show increased amygdala activation (Maheu et al., 2010; Dannlowski et al., 2012) and hippocampal activation (Maheu et al., 2010). When viewing sad faces, depressed adults with a history of childhood maltreatment demonstrate increased amygdala activation (Grant et al., 2011). These studies provide preliminary evidence for an association between childhood maltreatment and neural responses during emotional face processing; however, the ability to discriminate novel from familiar faces is also a critical component of face-processing ability.

Quickly determining whether a face is new or familiar serves multiple functions, including allocating attentional resources to determine whether a new person is safe or potentially threatening, and facilitating positive social interactions with familiar people. Novel faces may be particularly salient because novel faces represent an unknown – ambiguous and potentially threatening – social stimulus (Masten et al., 2008; Jovanovic et al., 2009). The key brain regions involved in face processing are also involved in novel face detection. For example, both the amygdala and hippocampus are involved in the detection of novel stimuli (Yamaguchi et al., 2004; Rutishauser et al., 2006; Blackford et al., 2010), including novel faces (Rossion et al., 2003; Wright et al., 2003; Pedreira et al., 2010). The FFA is also sensitive to slight differences in faces (Halgren et al., 2000), suggesting that a sensory-limbic network facilitates novel face processing. The effects of childhood maltreatment on the neural substrates of novel face processing remain unknown.

Both inhibited temperament and childhood maltreatment are associated with behavioral deficits in face and emotion recognition, as well as alterations in the neural network processing of faces. Furthermore, a trait related to inhibited temperament – early difficult temperament – has been associated with an increased incidence of childhood maltreatment (Cohen and Brooks, 1987). Therefore, in a population that is already genetically predisposed to altered face processing, exposure to childhood maltreatment may compound existing neural alterations. To test this hypothesis, we examined the effects of childhood maltreatment on neural responses to novel faces in a sensory-limbic network in a group of inhibited young adults.

2. Methods

2.1. Participants

Eighteen young adults with an inhibited temperament were included in this study. Participants, recruited from the Nashville community, were ages 19–30 at the time of the study and had a mean age of 23 years (S.D. 2.91 years); 67% were female. Only one participant was left-handed. Thirteen participants were Caucasian, three were African American, one participant was Hispanic, and one was Asian. Written informed consent was obtained from participants prior to enrollment in the study.

Data from these participants were previously reported (Blackford et al., 2011). The present study is a novel analysis testing the effect of childhood maltreatment on novel face processing in the inhibited temperament group. While our primary question of interest was focused on the effects of maltreatment in the genetically more vulnerable inhibited group, we performed a post-hoc analysis with the uninhibited group ($n=15$) to determine specificity of the observed effects. However, the uninhibited group has relatively low rates of maltreatment (mean=6.40, S.D. =7.87), which limits the ability to detect significant relationships between maltreatment and brain function.

2.2. Temperament measures

Temperament was assessed using two self-report instruments (Reznick et al., 1992): the Retrospective Self-report of Inhibition (RSRI; child) and the Adult Self-report of Inhibition (ASRI; adult). The RSRI is a 30-item assessment of behaviors during childhood and is scored on a Likert scale ranging from 1 to 5 (1=uninhibited, 5=inhibited). Example questions include: "Did you enjoy meeting new children your age?" and "Were you scared of the dark?" The ASRI is a 31-item assessment of current behaviors and is also scored a 1- to 5-point Likert scale. Example questions include: "Do you feel comfortable speaking in front of a large group of people?" and "Do open-air high places bother you?" Both measures have demonstrated reliability and validity in a non-selected sample (Reznick et al., 1992) and excellent reliability in this sample (Cronbach's alpha=0.84 and 0.82, respectively). Participants were determined to have inhibited temperament if they scored in the top 15% on both the RSRI and the ASRI scores based on normative population data (Reznick et al., 1992). The mean and standard deviations for RSRI and ASRI scores were 3.17 (S.D.=0.50) and 3.14 (S.D.=0.38).

2.3. Childhood maltreatment measures

To assess severity of childhood maltreatment, participants were also administered the Childhood Trauma Questionnaire (CTQ; Bernstein et al., 2003). This questionnaire assesses five types of maltreatment including emotional abuse, emotional neglect, physical abuse, physical neglect and sexual abuse. Participants rate items on the CTQ using a 5-point scale ranging from "never true" to "very often true." The CTQ has demonstrated reliability and validity (Scher et al., 2001; Paivio and Cramer, 2004), and reliability in this sample was high (Cronbach's alpha=0.92). The five childhood maltreatment subtypes scores are summed for a total CTQ score, which ranges from 25 to 125. To better reflect the frequency of maltreatment in our sample, we subtracted 25 from all CTQ total scores to create a range from 0 to 100, with a score of 0 reflecting no reported maltreatment. To determine reporting of significant maltreatment, we used thresholds suggested by Walker et al. (1999).

2.4. Psychiatric assessment

Participants were administered the structured clinical interview for Diagnostic and Statistical Manual (DSM)-IV (SCID; Spitzer et al. 1992) by a trained interviewer. As expected, six participants met criteria for at least one type of anxiety disorder (several participants met criteria for more than one disorder): social anxiety disorder ($n=5$), generalized anxiety disorder ($n=3$), specific phobia ($n=1$) and anxiety not otherwise specified (NOS; $n=2$). Two participants also met criteria for comorbid dysthymia and one participant met criteria for dysthymia alone.

2.5. Functional magnetic resonance imaging task

Participants completed a previously validated functional magnetic resonance imaging (fMRI) task involving passive viewing of both novel and recently familiarized faces with neutral expressions (Blackford et al., 2011; Schwartz et al., 2003). Stimuli were black and white images of human faces selected from two standard sets of emotional expressions (Lundqvist et al., 1998; Gur et al., 2001). All images were edited to ensure uniform face size, as well as eye and nose position. All extraneous features (e.g. shirt collars, hair) were removed. Stimuli were randomly selected for the novel or familiar group, and the two groups were balanced across gender and stimulus set. Participants were told while in the scanner, "In this study a face will appear in the middle of the screen. Your job is to stay focused on the screen and look at each face. The faces will flash quickly."

During a pre-test phase, participants were familiarized with a set of six faces presented during four blocks for a total of eight presentations of each face. During the test phase, participants were randomly presented familiar faces and novel faces during four separate runs. Within each run participants viewed 12 distinct novel and 12 familiar faces (each of the six familiar faces presented twice) for a