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Positive parenting predicts the development of adolescent brain structure: A longitudinal study

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ABSTRACT

Little work has been conducted that examines the effects of positive environmental experiences on brain development to date. The aim of this study was to prospectively investigate the effects of positive (warm and supportive) maternal behavior on structural brain development during adolescence, using longitudinal structural MRI. Participants were 188 (92 female) adolescents, who were part of a longitudinal adolescent development study that involved mother–adolescent interactions and MRI scans at approximately 12 years old, and follow-up MRI scans approximately 4 years later. FreeSurfer software was used to estimate the volume of limbic-striatal regions (amygdala, hippocampus, caudate, putamen, pallidum, and nucleus accumbens) and the thickness of prefrontal regions (anterior cingulate and orbitofrontal cortices) across both time points. Higher frequency of positive maternal behavior during the interactions predicted attenuated volumetric growth in the right amygdala, and accelerated cortical thinning in the right anterior cingulate (males only) and left and right orbitofrontal cortices, between baseline and follow up. These results have implications for understanding the biological mediators of risk and protective factors for mental disorders that have onset during adolescence.

1. Introduction

Adverse childhood environments represent an important risk factor for the development of psychopathology later in life (Heim and Nemeroff, 2001; Moran et al., 2004), and there is accumulating evidence that neurobiological changes (particularly with regard to brain structure) may mediate this relationship (Tupler and De Bellis, 2006). Indeed, there has been a recent surge of interest in the effects of adverse childhood environments on structural brain development, with a number of recent reviews highlighting the deleterious effects of adverse early environments on brain structure (Andersen and Teicher, 2008; Hart and Rubia, 2012; Lupien et al., 2009; McCrory et al., 2010).

Although a focus on the effects of adverse childhood environments on structural brain development is important and has implications for the development of targeted interventions for at-risk individuals, the influence of *positive* childhood environments on brain development is equally important to consider, given their importance

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for predicting positive life outcomes (e.g., Woolley and Grogan-Kaylor, 2006). In particular, positive (warm and supportive) parenting has been suggested as a critical environmental factor that has strong influences on child outcomes. Specifically, supportive parenting early in life has been shown to have positive effects on cognitive, behavioral, and psychological development throughout the lifespan (Beckwith et al., 1992; Eshel et al., 2006; Landry et al., 2008).

Despite this evidence, to date, little work has been conducted that examines the effects of positive parenting on brain structure in children and adolescents. Nonetheless, preliminary work has shown neurobiological effects of positive parenting, albeit with some inconsistent findings. For example, work that has shown that maternal support in early childhood predict larger hippocampal volumes in school-aged children (Luby et al., 2012). Other work, however, has found that higher-quality parental care early in life (i.e., age 4) predicted smaller hippocampal volumes during early-to-mid adolescence, as well as reduced gray matter in the anterior cingulate cortex (ACC) and thalamus (Rao et al., 2010). The latter study also found that parental nurturance later in childhood (i.e., age 8) predicted reduced gray matter in the orbitofrontal cortex (OFC) and fusiform cortex, and increased gray matter in the superior parietal and premotor cortices. Frye et al. (2010) found that adolescents who had experienced consistent responsive mothering during childhood had thinner cortex globally than those who had experienced inconsistent responsive mothering.

Though this research shows promise in elucidating the effects of positive parenting on brain structure, there are a number of gaps in the literature. First, the majority of research has focused on *early* (i.e., infancy and childhood) positive parenting factors, and has largely neglected the adolescent period. This is significant in that we and others have shown that positive parenting during the adolescent years is associated with favorable outcomes in terms of adjustment and mental health (Aquilino and Supple, 2001; Gaté et al., 2013; Schwarz et al., 2012). Further, the period of adolescence is characterized by marked neurodevelopment, second only to infancy in its extent (Andersen and Teicher, 2008). Thus, increased brain plasticity during this time may render the adolescent brain particularly sensitive to environmental influence (Bateson et al., 2004).

Second, to our knowledge, none of the existing research has assessed longitudinal measures of brain development. Such research is crucial for understanding how the neurobiological effects of positive parenting might change or unfold over time. This issue has been illustrated by findings that adverse environments have differential (and sometimes opposite) effects on brain structure when assessed in childhood versus adulthood (see McCrory et al., 2010; Tottenham and Sheridan, 2010), suggesting that the effects of parenting on the brain may not be static but are likely to change across the life span. A wealth of animal studies indicates that environmental enhancement has effects on brain development across the lifespan (Halperin and Healey, 2011). Further, other research has shown that development of cortical thickness during adolescence is related to cognitive and emotional functioning. For example, studies have found that accelerated cortical thinning in the ACC and OFC is associated with increased emotional and behavioral functioning (Ducharme et al., 2013; Shaw et al., 2006; Vijayakumar et al., in press-a, in press-b). It is of note that in these studies, exaggerations of the normative pattern of growth (i.e., cortical thinning, Shaw et al., 2006) appear to be 'optimal' (i.e., associated with superior functioning). Less research has investigated the relationship between volumetric change in subcortical structures and adolescent functioning. Our previous work has shown that decreased levels of psychopathology are associated with attenuated growth of the amygdala, and accelerated growth of the hippocampus, during adolescence (Whittle et al., 2013). For the hippocampus, this finding again appears to reflect exaggerated normative growth (Dennison et al., 2013; Ostby et al., 2009) as being 'optimal'. Our amygdala finding suggests that attenuated growth of the amygdala may be 'optimal', however, relating this finding to normative development is difficult, given that descriptions of normative amygdala growth during adolescence have been inconsistent (Dennison et al., 2013; Ostby et al., 2009). In any case, studies of adolescent brain development appear to be important for understanding risk processes for adolescent emotional and behavioral outcomes.

The aim of the current study was to examine the effects of positive parenting during early adolescence (i.e., 11–13) on structural brain development from early to midadolescence. Positive parenting was operationalized as the frequency of positive maternal behaviors displayed during observed conflictual interactions with their adolescent children. The display of positive behaviors in such contexts is thought to be particularly important for influencing outcomes. For example, we have found low levels of positive maternal behaviors during conflictual interactions to prospectively predict the onset of depressive disorders during adolescence (Schwartz et al., in press). We focused on the structural development of a number of cortical and subcortical regions of interest (ROIs), which were chosen based on (a) the premise that an adolescent's experience of their mother's positive behavior would primarily engage, and hence influence, neural circuitry implicated in processing positive cues from the environment (i.e., reward processing and learning) and in regulating emotion, and (b) the involvement of these regions in the research to date (e.g., Ducharme et al., 2013; Rao et al., 2010) that has found brain structural associations with aspects of positive parenting and associated indices of adolescent functioning.

The structures investigated in this study include the amygdala, hippocampus, dorsal and ventral striatum, OFC, and ACC. The striatum is thought to play a central role in synchronizing different aspects of reward and learning (Everitt and Robbins, 2005). The OFC and ACC have been associated with a number of cognitive, social and emotional functions, including mediating different aspects of reward-based decision-making (Bush et al., 2002; Kringelbach, 2005), and regulating emotion and behavior (Ochsner and Gross, 2005). The amygdala and hippocampus are thought to be involved in the detection and representation of affectively salient stimuli, and in relaying information about emotional valence and salience for further processing (Habel et al., 2005; Haber et al., 2006).