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Adolescent neurodevelopment of cognitive control and risk-taking in negative family contexts☆

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ABSTRACT

Adolescents have an increased need to regulate their behavior as they gain access to opportunities for risky behavior; however, cognitive control systems necessary for this regulation remain relatively immature. Parents can impact their adolescent child's abilities to regulate their behavior and engagement in risk taking. Since adolescents undergo significant neural change, negative parent–child relationship quality may impede or alter development in prefrontal regions subserving cognitive control. To test this hypothesis, 20 adolescents completed a Go/NoGo task during two fMRI scans occurring 1 year apart. Adolescents reporting greater family conflict and lower family cohesion showed longitudinal increases in risk-taking behavior, which was mediated by longitudinal increases in left VLPFC activation during cognitive control. These results underscore the importance of parent–child relationships during early adolescence, and the neural processes by which cognitive control may be derailed and may lead to increased risk taking.

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Introduction

One of the most important skills adolescents need to successfully develop is cognitive control. While certainly important during childhood, the ability to regulate one's impulses and behavior becomes increasingly crucial as children transition into adolescence, a time when risk-taking behavior increases substantially. Adolescence involves both the biological transition of puberty, characterized by dramatic physical (Wheeler, 1991) and hormonal (Susman et al., 1985) changes, with a shift in social contexts and roles (Nelson et al., 2005). Adolescents rapidly gain access to a number of potentially dangerous activities such as drugs and alcohol use (Kandel and Logan, 1984), driving (U.S. Census Bureau, 2012), and sexual debut (Cavazos-Rehg et al., 2009). Unfortunately, cognitive control abilities, and the prefrontal cortex which subserves them, remain relatively immature into and through adolescence (Luna et al., 2010). As a result, adolescents have difficulties regulating their impulsive behavior, placing them at increased risk for health compromising outcomes such as sexually-transmitted infection (Kaestle et al., 2005), substance abuse (Santor et al., 2000), school failure (Nelson and DeBacker, 2008), and accidents or death (U.S. Census Bureau, 2012). As such, adolescents' cognitive control abilities can have far-reaching implications for health and successful adjustment.

The quality of family relationships may facilitate adolescents' cognitive control abilities. This may occur through parents' modeling of self-regulation (Eisenberg et al., 2005; Morris et al., 2007), protecting adolescents from stress (Power, 2004), and providing support for adolescents' autonomous regulation (Eccles et al., 1997; Morris et al., 2007). Parent–child relationships characterized by conflict and stress reduce opportunities for adolescents to develop effective cognitive skills, which can increase the likelihood of subsequent risk-taking behaviors (McNeely et al., 2002; Telzer et al., 2014a). Indeed, the quality of parent–adolescent relationships influences sexual debut and riskiness (McNeely et al., 2002; Miller, 2002; Clawson and Reese-Weber, 2003), risky driving practices (Michael and Ben-Zur, 2007), and substance use (Borawski et al., 2003; Telzer et al., 2014a) such that hostility and conflict in family relationships puts teens at increased risk for these negative outcomes. Due to the costly consequences of adolescent risk taking (U.S. Census Bureau, 2012), understanding how parents contribute both positively and negatively to adolescent engagement in risky behaviors has important social and health implications.

Parents may influence their adolescents' engagement in risk taking, in part, through the influence of parenting on neural development. Similar to the early postnatal period, adolescence involves an increase in neural plasticity and reorganization (Casey et al., 2005), such that neural systems are particularly sensitive to social influences (Blakemore and Mills, 2014; Knoll et al., 2015). This increase in social salience may make adolescents more susceptible to the impacts of poor parent–

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child relationships. Although parent–child relationships during early postnatal development set the stage for future neural trajectories (Schore, 2001; Gee et al., 2013; Tottenham, 2014), little attention has been paid to the effects of parent–child relationships during adolescence. There is evidence to suggest that adolescents' neural activity in some domains (e.g., affective processing) is modulated by parent–child attachment quality (Gee et al., 2013, 2014; Olsavsky et al., 2013) and structural differences emerge across adolescence in affective and prefrontal regions as a function of earlier positive parent–child interactions (Whittle et al., 2014). However, relatively little is known about the effects of parents on adolescent neural networks involved specifically in cognitive control, which is a significant limitation given that parents play a significant role in the development of youths' basic executive functioning (Deater-Deckard, 2014). Moreover, most neuroimaging studies have explored the effects of family relationships on neural processing using cross-sectional (i.e., single-time point) approaches (but see Qu, Fuligni, Gálvan, & Telzer, 2015). Because adolescence is a time of significant neural changes (Paus, 2005; Lenroot et al., 2007), these snapshots of neural activity may miss how parenting can have effects on adolescents' neural trajectories over time. In particular, by comparing individuals to their own baseline measurements, longitudinal approaches can offer insights into contextual factors which influence ongoing development. Compared with traditional cross-sectional approaches, longitudinal methodologies allow us to examine how specific factors (e.g., family relationships) are associated with changes in developmental trajectories at the individual level and offer a more-precise estimate of how these factors mediate changes in ongoing developmental processes (Maxwell and Cole, 2007). Additionally, longitudinal approaches have increased power to detect changes of interest relative to cross-sectional approaches by examining within-person change and has the benefit of controlling for differences that exist between cohorts compared in cross-sectional analyses (Louis et al., 1986).

To address these gaps in our understanding, we examined the impact of family relationship quality on longitudinal changes in risk taking across early adolescence, as well as the neural processes that may underlie this link. We examined both neural and behavioral changes as adolescents transitioned from the 8th to the 9th grades, a developmental transition marked by increases in risk-taking behaviors such as substance use (Bryant et al., 2003) and sexual initiation (Santelli et al., 2004). Additionally, adolescent–parent relationships during this period are often characterized by increased conflict as adolescents attempt to negotiate increased independence (McGue et al., 2005). Finally, on the neural level, large-scale developmental changes continue through this period, suggesting that neural systems remain plastic and especially sensitive to social and environmental input (Crone and Dahl, 2012; Blakemore and Mills, 2014). Importantly, neural regions in the lateral prefrontal cortex (PFC), which subserve cognitive control, are among the last to reach maturity, continuing to develop throughout the teenage years (Lenroot et al., 2007; Shaw et al., 2008). This prolonged maturation provides an extended window for environmental factors to exert influence on the development of the lateral PFC and associated cognitive control abilities (Nelson & Guyer, 2011) with downstream consequences for adolescents' engagement in risk-taking behavior (Casey et al., 2008). In the current study, we focused on the ventrolateral prefrontal cortex (VLPFC), a region involved in behavioral inhibition and cognitive control (Swick et al., 2008; Souza et al., 2009; Levy and Wagner, 2011). Moreover, recent studies have shown that longitudinal increases in VLPFC activation during a risk-taking task predict longitudinal increases in risk taking behaviors (Qu, Galvan, Fuligni, Lieberman, & Telzer, 2015), and changes in positive family interactions are associated with longitudinal decreases in lateral PFC activation among older adolescents (Qu, Fuligni, Gálvan, & Telzer, 2015). Following this prior work, and building off the extant literature linking family relationships with cognitive control abilities, we hypothesized that negative family relationships would be associated with longitudinal increases in VLPFC activation during a cognitive control task, and these neural changes would explain the link between negative family relationships and increased risk taking. We utilized a longitudinal design, which allowed us to examine how the quality of family relationships predicts individual trajectories in risk taking via changes in neural processing.

Methods

Participants

Twenty (13 male) healthy adolescents participated in the current study. Participants were studied at two time-points, once during 8th grade and again during 9th grade. All adolescents were 14 at Time 1 (T1: M_{age} = 14.39 years, SD = .34) and 15 at Time 2 (T2: M_{age} = 15.20, SD = .31). Three additional adolescents participated, but are not included in the current study (one participant moved excessively (>2.0 mm) and two did not complete self-report measures at T1). Participants provided written consent and assent in accordance with the policies of the University of Illinois' Institutional Review Board.

Self report measures

Family relationship quality

At T1 and T2, participants completed two self-report measures related to family relationship quality. The first asked participants to report on family conflict (Ruiz et al., 1998). Participants completed 10 questions about their relationship with their parents in the last month (e.g., "You and your parents had a serious argument or fight" and "You and your parents yelled or raised your voices at each other"). Participants used a 5-point scale to rate the frequency with which they and their parents engaged in these behaviors (1 = "Almost never" to 5 = "Almost always"). The measure had good reliability (α: T1 = .94, T2 = .93). Participants also reported on their family cohesion (FACES II; Olson et al., 1979). Participants completed 10 questions (e.g., "My mother/father and I feel very close to each other" and "My mother/father and I avoid each other at home") on the same 5-point scale. Questions for the family cohesion score were reverse coded such that a higher score reflected less cohesive family relationships. This measure had good reliability (α: T1 = .91, T2 = .88). The two measures were positively correlated (T1: r = .55, p = .01; T2: r = .45, p = .04), and were combined into a composite family relationship score, with higher scores representing greater levels of family conflict and lower levels of family cohesion.

Adolescent risk taking

In order to examine changes in risk taking, adolescents completed a modified version of the Adolescent Risk-Taking Scale at both T1 and T2 (Alexander et al., 1990; Telzer et al., 2013). Participants responded to 12 questions indicating how often (1 = "Never" to 4 = "Many times") they engaged in a range of risky behaviors (e.g., "I have stolen or shoplifted" or "I have had sex without using protection"). The scale had good reliability at both time points (α: T1 = .76; T2 = .89).

Cognitive control task

At both time points, adolescents performed a Go–NoGo (GNG) task during an fMRI scan. Participants were presented with brief (500 ms) trials which consisted of a single letter and were instructed to respond with a button press as quickly as possible to all letters (Go trials) except for Xs (NoGo trials). X trials occurred 25% of the total number of trials. This high ratio of Go trials reliably causes participants to develop a pre-potent response to perform a button press that must be inhibited during NoGo trials. Trials were separated by a fixation period that varied in length with a gamma distribution (M = 1000 ms). Participants completed four blocks of the task. Each block was composed of 80 trials (60 Go; 20 NoGo), and blocks were separated by a 60 s rest period. Efficacy of cognitive control was measured as successful inhibition of the button press during NoGo trials.