NeuroImage 82 (2013) 23–34

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

Risk-taking and social exclusion in adolescence: Neural mechanisms underlying peer influences on decision-making

Shannon J. Peake [a], Thomas J. Dishion [b], Elizabeth A. Stormshak [c], William E. Moore [a], Jennifer H. Pfeifer [a,*]

[a] Department of Psychology, University of Oregon, USA
[b] Department of Psychology, Arizona State University, USA
[c] College of Education, University of Oregon, USA

ARTICLE INFO

Article history:
Accepted 15 May 2013
Available online 24 May 2013

ABSTRACT

Social exclusion and risk-taking are both common experiences of concern in adolescence, yet little is known about how the two may be related at behavioral or neural levels. In this fMRI study, adolescents (N = 27, 14 male, 14–17 years-old) completed a series of tasks in the scanner assessing risky decision-making before and after an episode of social exclusion. In this particular context, exclusion was associated with greater behavioral risk-taking among adolescents with low self-reported resistance to peer influence (RPI). When making risky decisions after social exclusion, adolescents who had lower RPI exhibited higher levels of activity in the right temporoparietal junction (rTPJ), and this response in rTPJ was a significant mediator of the relationship between RPI and greater risk-taking after social exclusion. Lower RPI was also associated with lower levels of activity in lPFC during crashes following social exclusion, but unlike rTPJ this response in lPFC was not a significant mediator of the relationship between RPI and greater risk-taking after social exclusion. The results suggest that mentalizing and/or attentional mechanisms have a unique direct effect on adolescents' vulnerability to peer influence on risk-taking.

Introduction

Social interactions take on increased importance in adolescence (Crone and Dahl, 2012) and often provide the context in which teens make decisions to engage in risky behaviors such as substance use, health-risking sexual behavior, and reckless driving (Dishion and Owen, 2002; La Greca et al., 2001; Simons-Morton et al., 2005). One particularly powerful and distressing form of social interaction is exclusion or rejection by peers (Williams, 2007), which can negatively affect individual and interpersonal behavior through decreased self-regulation (Baumeister et al., 2005), aggression (Ayduk et al., 2008), and self-defeating actions (Twenge et al., 2002). Although previous neuroimaging studies have examined risky decisions and associated neural processes in adolescence (Bjork et al., 2007; Burnett et al., 2010; van Leijenhorst et al., 2010) little is currently known about the neural mechanisms relating social exclusion and subsequent risk-taking behavior. This study employed functional magnetic resonance imaging (fMRI) to examine the behavioral and neural consequences of social exclusion on risky decision-making.

Neuroimaging and adolescent risk-taking

Biological factors contributing to adolescent risky decision-making have been explored using neuroimaging methods in combination with tasks that examine reward processing and cognitive control. For example, reward sensitivity (specifically, reactivity during anticipation of rewards) typically exhibits a non-linear trajectory that peaks in adolescence relative to childhood and adulthood (Ernst et al., 2005; Galvan, 2010; Galvan et al., 2006; Geier et al., 2010; Somerville et al., 2011; Van Leijenhorst et al., 2010), although there are some exceptions to this pattern (e.g., Bjork et al., 2004). Further, greater neural responses in the ventral striatum (VS) during reward anticipation is associated with more drug use (Bjork et al., 2011), and responses in nucleus accumbens to reward outcomes are stronger in teens with externalizing disorders that are often associated with risk behavior (Bjork et al., 2010). In addition, adolescents can show decreased neural activity in cognitive regulatory structures such as lateral prefrontal cortex (lPFC) during risk decisions compared to adults (e.g., Eshel et al., 2007), but the evidence for this pattern is mixed (Crone and Dahl, 2012).

Based on these results and findings from animal models of adolescence (Spear, 2011), imbalances between the maturation rates of cortical and subcortical regions respectively associated with cognitive control and reward have been proposed as an explanation for heightened adolescent risk-taking (Casey et al., 2011; Ernst et al., 2009; Somerville et al., 2010; Steinberg, 2008, 2010). These models suggest that approach

* Corresponding author at: Department of Psychology, 1227 University of Oregon, Eugene, OR 97403-1227, USA.
E-mail address: jpfeifer@uoregon.edu (J.H. Pfeifer).

1053-8119/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.neuroimage.2013.05.061

or reward-seeking systems develop earlier in adolescence than avoidance or control systems, resulting in an imbalance that leads to heightened sensitivity to reward cues and insufficient cognitive control. However, outstanding methodological questions and results inconsistent with these models (Blakemore and Robbins, 2012; Johnson et al., 2009; Pfeifer and Allen, 2012; Romer, 2010) suggest that additional factors play a role in adolescent risky decision-making.

Social exclusion and adolescent risk-taking

Rejection, exclusion, and ostracism are all associated with various forms of negative behavior (Williams, 2007). However, these terms can refer to different types of experiences, ranging from chronic rejection over time to a single episode of exclusion (Leary, 2005). Within the developmental literature on peer relations, the term peer rejection generally refers to the social status of a child based on sociometric methods (i.e., peer nominations of children that are least liked), and represents cumulative effects of negative social treatment by peers (Coie et al., 1992; Dodge et al., 2003). Longitudinal studies link chronic peer rejection in childhood with increased risk-taking during adolescence in forms such as externalizing behavior, truancy, substance use, and association with deviant peers (Dishion et al., 1995; Prinstein and La Greca, 2004). Other approaches alternately use the terms rejection, exclusion, or ostracism to refer to an event in which an individual is left out of a group or denied participation in some activity (Williams, 2007). In this manuscript, we use the term social exclusion to denote a single event or episode, and we use the term rejection in the more general sense of a person or group indicating that they do not value a personal relationship (Leary, 2005). Repeated experiences of rejection by peers, such as those experienced by youth receiving a "rejected" sociometric status using peer nomination techniques, are referred to here by the term chronic peer rejection.

Single experiences of social exclusion have been linked to decreased self-regulation (Baumeister et al., 2005; DeWall et al., 2008), poor health choices (Oaten et al., 2008), and taking irrational, self-defeating risks (Twenge et al., 2002). In addition, reactions to social exclusion can include aggression (Ayduk et al., 2008; Twenge et al., 2007), attempts to affiliate (Maner et al., 2007), or negative social actions (Carter-Sowell et al., 2008; Mallott et al., 2009), any of which could conceivably take the form of risk-taking behavior in peer contexts. That is, teens with threatened or unmet social needs might engage in risky activities or behaviors as a way to interact with or gain the recognition of peers. It is also possible that adolescents might respond to exclusion with risky behavior as a way of establishing a non-conforming identity, in effect "rejecting the rejectors" (Sampson and Laub, 1997). Factors affecting the emotional magnitude and specific behavioral reactions to exclusion can vary by individual and context (Molden et al., 2009; Smart Richman and Leary, 2009). Adolescents with poor social skills or low self-esteem may be more likely to experience rejection (Leary et al., 1995) and may be more emotionally affected than less vulnerable teens (Prinstein and Aikins, 2004). More generally, susceptibility to peer influence varies by individual, and differences in the ability to resist peer influence are significant predictors of real-world risk behavior (Monahan et al., 2009; Steinberg and Monahan, 2007).

Neuroimaging of mentalizing in adolescence

A growing body of neuroimaging research examines the systems supporting various facets of adolescent social cognition that are relevant to peer relationships and social influences on decision-making (Pfeifer and Blakemore, 2012). One particularly relevant facet of adolescent social cognition that has been examined using fMRI is mentalizing, or the ability to apprehend others' mental states such as thoughts or feelings, and to use this information to understand others' behavior (Frith and Frith, 2007). According to a recent meta-analysis (Van Overwalle and Baetens, 2009), multiple complementary neural systems have been implicated in mentalizing. One set of regions, composed of temporoparietal junction (TPJ) and the cortical midline structures (CMS) including medial prefrontal and posterior parietal cortices (mPFC, mPPC) is responsive to more abstract representations of the thoughts and perspectives of others (Uddin et al., 2007).

A relatively consistent pattern in this line of inquiry is that adolescents exhibit enhanced reactivity in mPFC during mentalizing, relative to adults (Blakemore, 2008, 2011; Blakemore et al., 2007, 2010; Burnett et al., 2008; Gunther Moor et al., 2012; Pfeifer and Blakemore, 2012; Pfeifer et al., 2009; van den Bos et al., 2011; Wang et al., 2006). Another emerging developmental pattern is a linear increase in TPJ responses during mentalizing (Gweon et al., 2012; van den Bos et al., 2011). Prior work in our laboratory suggests that adolescents and adults also utilize TPJ to ascertain what others (parents, friends, and peers) think specifically about one's self (Pfeifer et al., 2009), and that adolescents engage in this reflective perspective-taking even when they are not prompted to do so. Taken together, this research suggests that when exploring peer influences on adolescent decision-making, it may be profitable to consider not only the VS and lPFC responses that are associated with risk decisions, but also the potential contribution of mentalizing responses in TPJ and CMS (mPFC and mPPC).

A recent and highly relevant study examining peer influence on decision-making, for example, concluded that the presence of peers during risk decisions heightened responses in VS and orbitofrontal cortex (OFC) more for adolescents than adults (Chein et al., 2011). The degree to which responses in VS increased under peer influence was inversely related to self-reported resistance to peer influence. Adults engaged lPFC more than adolescents, but this was not impacted by peer presence. One interpretation of these findings is in that particular context, peer influences on risk-taking in adolescence might be mediated by heightened VS and OFC responses that represent enhanced reward sensitization, rather than diminished cognitive control. Complicating this view, however, are studies in which adolescents exhibit *decreased* VS response to some reward conditions (Bjork et al., 2010; Geier et al., 2010; and van Leijenhorst et al., 2010), or *increased* VS activity is associated with more adaptive functioning such as increased resistance to peer influence and decreased risky behavior (Pfeifer et al., 2011). Collectively, these results suggest the existence of additional mechanisms for peer influence on decision-making during adolescence that vary according to the *kind* of social context experienced.

Current study

To examine the neural mechanisms underlying the effects of social exclusion on risk decisions in adolescence, the current study combines a behavioral measure of risk-taking (the Stoplight task; Gardner and Steinberg, 2005) with a manipulation producing an experience of social exclusion (the Cyberball game; Williams et al., 2000). The Stoplight task features a series of intersections at which subjects must decide whether to stop for a yellow traffic light (safe option) or try to make it through the intersection (risk option). While the risk option often results in a faster time, it is accompanied by the possibility of crashing and losing time if another car crosses the intersection. The social aspect of the study comes from the presence and actions of two hypothetical peers (implied to be watching the participant via Internet connection). After being trained on the task by playing five rounds alone (to eliminate learning effects), the subjects first complete the Stoplight task while the peers are watching, then play the Stoplight task again after an experience of being excluded from a different game by the peers. During the second Stoplight task, the subject is being watched by the same peers that just excluded them. This manipulation creates an additional layer of risk decision factors representing the subject's expected social evaluation of his or her performance by the peers, above and beyond the risk decisions of the task.