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Peer Influences on Adolescent Decision Making

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Abstract

Research efforts to account for elevated risk behavior among adolescents have arrived at an exciting new stage. Moving beyond laboratory studies of age differences in "cool" cognitive processes related to risk perception and reasoning, new approaches have shifted focus to the influence of social and emotional factors on adolescent neurocognition. We review recent research suggesting that adolescent risk-taking propensity derives in part from a maturational gap between early adolescent remodeling of the brain's socio-emotional reward system and a gradual, prolonged strengthening of the cognitive control system. At a time when adolescents spend an increasing amount of time with their peers, research suggests that peer-related stimuli may sensitize the reward system to respond to the reward value of risky behavior. As the cognitive control system gradually matures over the course of the teenage years, adolescents grow in their capacity to coordinate affect and cognition, and to exercise self-regulation even in emotionally arousing situations. These capacities are reflected in gradual growth in the capacity to resist peer influence.

> "…it seems like people accept you more if you're, like, a dangerous driver or something. If there is a line of cars going down the road and the other lane is clear and you pass eight cars at once, everybody likes that. […] If my friends are with me in the car, or if there are a lot of people in the line, I would do it, but if I'm by myself and I didn't know anybody then I wouldn't do it. That's no fun.'"
>
> Anonymous teenager, as reported in The Culture of Adolescent Risk-Taking (Lightfoot, 1997; p.10)

It is well-established that adolescents are more likely than children or adults to take risks, as evinced by elevated rates of experimentation with alcohol, tobacco, and drugs, unprotected sexual activity, violent and nonviolent crime, and reckless driving (Steinberg, 2008). Early research efforts to identify the distinguishing cognitive immaturity underlying adolescents' heightened risk-taking propensity bore little fruit. A litany of carefully-controlled laboratory experiments contrasted adolescent and adult capacities to perceive and process fundamental components of risk information, but found that adolescents possess the knowledge, values,

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and processing efficiency to evaluate risky decisions as competently as adults (Reyna & Farley, 2006).

If adolescents are so risky in the real world, why do they appear so risk-averse in the lab? We propose that the answer to this question is nicely illustrated by the American teenager quoted above: "*…if I'm by myself and I didn't know anybody then I wouldn't do it. That's no fun*." If adolescents made all of their decisions involving drinking, driving, dalliances, and delinquency in the cool isolation of an experimenter's testing room, those decisions would likely appear as risk-averse as those of adults. But therein lies the rub: teenagers spend a remarkable amount of time in the company of other teenagers. This paper describes a new wave of research on the neurobehavioral substrates of adolescent decision making *in peer contexts* suggesting that the company of other teenagers fundamentally alters the calculus of adolescent risk taking.

Peer Influences on Adolescent Risk Behavior

Consistent with self-reports of lower resistance to peer influence among adolescents than adults (Steinberg & Monahan, 2007), observational data point to the role of peer influences as a primary contextual factor contributing to adolescents' heightened tendency to make risky decisions. For instance, crime statistics indicate that adolescents typically commit delinquent acts in peer groups, whereas adults more frequently offend alone (Zimring, 1998). Furthermore, one of the strongest predictors of delinquent behavior in adolescence is affiliation with delinquent peers, an association that has been attributed in varying proportions to peer socialization (e.g., "deviancy training"; Dishion, Bullock, & Granic, 2002) and friendship choices, wherein risk-taking adolescents naturally gravitate toward one another (e.g., Bauman & Ennett, 1996). Given the difficulty of distinguishing between these causal alternatives with correlational data, our lab has pursued a program of experimental research directly comparing the behavior of adolescents and adults when making decisions either alone, or in the presence of their peers.

In the first experimental study to examine age differences in the effect of peer context on risky decision making (Gardner & Steinberg, 2005), early adolescents (mean age = 14), late adolescents (mean age = 19), and adults (mean age = 37) were tested on a computerized driving task, called the "Chicken Game," which challenges the driver to advance a vehicle as far as possible on the driving course, while avoiding a crash into a wall that could appear, without warning, at any point on the course. Peer context was manipulated by randomly assigning each group of three participants to play the game either individually (alone in the room), or with two same-aged peers in the room. When tested alone, the participants from each of the three age groups engaged in a comparable amount of risk taking. In contrast, early adolescents scored twice as high on an index of risky driving when tested with their peers in the room than when alone, whereas late adolescents were approximately 50% riskier in groups, and adults showed no difference in risky driving related to social context. The ongoing goal of our research program is to further specify the behavioral and neural mechanisms of this peer effect on adolescent risk taking.

A Neurodevelopmental Model of Peer Influences on Adolescent Decision Making

Building on extensive evidence demonstrating maturational changes in brain structure and function occurring across the second decade of life (and frequently beyond), we have advanced a neurodevelopmental account of heightened susceptibility to peer influence among adolescents (Steinberg, 2008; Albert & Steinberg, 2011). In brief, we propose that, among adolescents more than adults, the presence of peers “primes” a reward-sensitive motivational state that increases the subjective value of immediately available rewards and thereby increases the probability that adolescents will favor the short-term benefits of a risky choice over the long-term value of a safe alternative. Although a comprehensive presentation of the behavioral and neuroscientific evidence underlying this hypothesis is beyond our current scope (but see Albert & Steinberg, 2011), a brief review of three fundamental assumptions of this model will set the stage for a description of our peer influence studies.

First, decisions are a product of both cognitive *and affective* input, even when affect is unrelated to the choices under evaluation

Research based on adult populations has identified several pathways by which affect influences decision making (Loewenstein, Weber, Hsee, & Welch, 2001). For instance, the *anticipated* emotional outcome of a behavioral option -- how one expects to feel after making a given choice --contributes to one's cognitive assessment of its expected value. Indeed, affective states may influence decision processing even when the source of the affect is not directly related to the choices under evaluation. Such *incidental* affective influences are apparent in experiments demonstrating the effect of pre-existing or experimentally elicited affective states on adult perception, memory, judgment, and behavior (Winkielman, Knutson, Paulus, & Trujillo, 2007). One experiment illustrating this effect found that elicitation of incidental positive emotion (via presentation of masked happy faces) caused participants to pour and drink more of a novel beverage than participants who had viewed angry faces, despite no differences in self-reported emotion between the two groups (Winkielman, Berridge, & Wilbarger, 2005). Consistent with evidence for extensive overlap in the neural circuitries implicated in the evaluation of socio-emotional and choice-related incentive cues (e.g., ventral striatum, ventromedial prefrontal cortex; for a recent review, see Falk, Way, & Jasinska, 2012), Winkielman and colleagues describe this priming effect as an instance of *approach sensitization*. That is, neural responses to positively valenced socio-emotional stimuli – in this case, responses not even reaching the level of conscious awareness – may sensitize approach (i.e., “GO”) responding to unrelated incentive cues. As we describe below, several characteristics of adolescent neurobehavioral functioning suggest that this approach sensitization effect could be a particularly powerful influence on adolescent decision making in peer contexts.

Second, adolescents exhibit stronger "bottom-up" affective reactivity than adults in response to socially relevant stimuli

Whereas some controversy remains regarding the degree to which adolescents are more or less sensitive than children and adults to non-social reward cues (Galvan, 2010; Spear, 2009), few scholars now dispute that adolescence is a period of peak neurobehavioral sensitivity to social stimuli (Burnett, Sebastian, Kadosh, & Blakemore, 2011; Somerville, *this issue*). Puberty-related increases in gonadal hormones have been linked to a proliferation of receptors for oxytocin within subcortical and limbic circuits, including the amygdala and striatum (Spear, 2009). Oxytocin neurotransmission has been implicated in a variety of social behaviors, including facilitation of social bonding and recognition and memory for positive social stimuli (Insel & Fernald, 2004). Alongside concurrent changes in dopaminergic function within neural circuits broadly implicated in incentive processing (Spear, 2009), these puberty-related increases in gonadal hormones and oxytocin receptor density contribute to changes in a constellation of social behaviors observed in adolescence.

Peer relations are never more salient than in adolescence. In addition to a puberty-related spike in interest in opposite-sex relationships, adolescents spend more time than children or adults interacting with peers, report the highest degree of happiness when in peer contexts, and assign greatest priority to peer norms for behavior (Brown & Larson, 2009). This developmental peak in affiliation motivation appears highly conserved across species: Adolescent rats also spend more time than younger or older rats interacting with peers, while showing evidence that such interactions are highly rewarding (Doremus-Fitzwater, Varlinskaya, & Spear, 2010). Moreover, several developmental neuroimaging studies indicate that, relative to children and adults, adolescents show heightened neural activation in response to a variety of social stimuli, such as facial expressions and social feedback (Burnett et al., 2011). For instance, one of the first longitudinal neuroimaging studies of early adolescence demonstrated a significant increase from ages 10 to 13 in ventral striatal and ventral prefrontal reactivity to facial stimuli (Pfeifer et al., 2011). Together, this evidence for hypersensitivity to social stimuli suggests that adolescents may be more likely than adults to generate a baseline state of heightened approach motivation when exposed to positively valenced peer stimuli in a decision-making scenario, thus setting the stage for an exaggerated approach sensitization effect of peer context on risky decision making.

Third, adolescents are less capable than adults of "top-down" cognitive control of impulsive behavior

In contrast to the relatively sudden changes in social processing that occur around the time of puberty, cognitive capacities supporting efficient self-regulation mature in a gradual, linear pattern over the course of adolescence. In developmental parallel with structural brain changes thought to support neural processing efficiency (e.g., increased axonal myelination), adolescents show continued gains in response inhibition, planned problem solving, flexible rule use, impulse control, and future orientation (Steinberg, 2008). Indeed, evidence is growing for a direct link between structural and functional brain maturation during adolescence and concurrent improvements in cognitive control. In addition to studies correlating white matter maturation with age-related cognitive improvements (Schmithorst & Yuan, 2010), developmental neuroimaging studies utilizing tasks requiring response inhibition (e.g., Go-No/Go, Stroop, flanker tasks, ocular antisaccade) describe relatively inefficient recruitment by adolescents of the core neural circuitry supporting cognitive control (e.g., lateral prefrontal and anterior cingulate cortex) (Luna, Padmanabhan, & O'Hearn, 2010). Moreover, research on age differences in control-related network dynamics demonstrate adolescent immaturity in the *functional integration* of neural signals deriving from specialized cortical and subcortical "hub" regions (Stevens, 2009). This immature capacity for functional integration may contribute to adolescent difficulties in simultaneously evaluating social, affective, and cognitive factors relevant to a given decision, particularly when social and emotional considerations are disproportionately salient.

Identification of Mechanisms Underlying Peer Influences on Adolescent Decision Making

In an effort to further specify the neurodevelopmental vulnerability underlying adolescent susceptibility to peer influence, we have conducted a series of behavioral and neuroimaging experiments comparing adolescent and adult decision making in variable social contexts. Specifically, we have sought to determine whether the presence of peers biases adolescent decision making by (a) modulating responses to incentive cues, consistent with the approach sensitization hypothesis, (b) disrupting inhibitory control, or (c) altering both of these processes. As a first step in addressing this question, we conducted an experiment that randomly assigned late adolescents (ages 18 and 19) to complete a series of tasks either alone or in the presence of two same-age, same-sex peers. Risk-taking propensity was assessed using the "Stoplight" game, a first-person driving game wherein participants must advance through a series of intersections to reach a finish line as quickly as possible to receive a monetary reward (Figure 1). Each intersection is marked by a stoplight that turns yellow (and sometimes red) as the car approaches, and participants must decide to either "hit the brakes" (and lose time while waiting for the light to turn green) or run the light (and risk crashing while crossing through an intersection). We also administered tasks for cognitive control (Go/No-Go) and preference for immediate-over-delayed rewards (Delay Discounting). Whereas no group differences were evident on the Go/No-Go index of inhibitory control, adolescents in the peer presence condition took more risks on the Stoplight task (Albert et al., 2009) and indicated stronger preference for immediate-over-delayed rewards (O'Brien, Albert, Chein, & Steinberg, 2011), relative to adolescents who completed the tasks alone.

Findings from a recent follow-up experiment suggest that peer observation influences adolescents' decision making even when the peer is anonymous and not physically present in the same room. Utilizing a counterbalanced, repeated-measures design, we assessed the task performance of late adolescents once in a standard "alone" condition, and once in a deception condition that elicited the impression that their task performance was being observed by a same-age peer in an adjoining room. As predicted, participants exhibited stronger preference for immediate rewards on a delay discounting task when they believed they were being observed, relative to alone (Weigard, Chein, & Steinberg, 2011). Peer observation also resulted in a higher rate of monetary gambles on a probabilistic gambling task, but only for participants with relatively lower self-reported resistance to peer influence (Smith, Chein, & Steinberg, 2011). Along similar lines, Segalowitz et al. (2012) report that individuals high in self-reported sensation seeking are especially susceptible to the peer effect on risk taking. Considered together, these behavioral results suggest that peer presence increases adolescents' risk taking by increasing the salience (or subjective value) of immediately available rewards, and that some adolescents are more susceptible to this effect than others.

Our recent work has utilized brain imaging to more directly examine the neural dynamics underlying adolescent susceptibility to peer influences. In the first of these studies, we scanned adolescents and adults while they played the Stoplight game, again utilizing a counterbalanced within-subjects design (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011). All subjects played the game in the scanner twice -- once in a standard "alone" condition, and once in a "peer" condition, wherein they were made aware that their performance was being observed on a monitor in a nearby room by two same-age, same-sex peers who had accompanied them to the experiment. As predicted, adolescents but not adults took significantly more risks when observed by peers than when alone (Figure 2). Furthermore, analysis of neural activity during the decision-making epoch showed greater activation of brain structures implicated in reward valuation (ventral striatum and orbitofrontal cortex) for adolescents in the peer relative to the alone scans, an effect that was not apparent for adults (Figure 3). Indeed, the degree to which participants (across all ages) evinced peer-greater-than- alone activation in the ventral striatum was inversely correlated with self-reported resistance to peer influence (Figure 4). This study represents the first evidence that peer presence accentuates risky decision making in adolescence by modulating activity in the brain's reward valuation system.

Conclusions and Future Directions

Although our work to date has indicated that the effect of peers on adolescent risk taking is mediated by changes in reward processing, we recognize that the distinction between risk taking that is attributable to heightened arousal of the brain's reward system versus that which is due to immaturity of the cognitive control system is somewhat artificial, since these brain systems influence each other in a dynamic fashion. Consistent with this notion, in a comparison of children, adolescents, and adults on a task that requires participants to either produce or inhibit a motor response to pictures of calm or happy faces, Somerville, Hare, and Casey (2011) not only found elevated ventral striatal activity for adolescents in response to happy faces, which the authors discuss as an "appetitive" cue, but also a corresponding increase in failures to inhibit motor responses to the happy relative to the calm facial stimuli. Thus, adolescents' exaggerated response to positively-valenced social cues is shown here to directly undermine their capacity to inhibit approach behavior. Translated to the peer context, this finding suggests that adolescents may not only be particularly sensitive to the reward-sensitizing effects of social stimuli, but that this sensitization may further undermine their capacity to "put the brakes on" impulsive responding.

Despite the promise of this conceptual model, further work is needed to specify the neurodevelopmental dynamics underlying adolescent susceptibility to peer influence, and to translate this understanding to the design of effective prevention programs. In an effort to "decompose" the peer effect, we are currently examining age differences in the influence of social cues on neural activity underlying performance on tasks specifically tapping reward processing and response inhibition. In addition, we are investigating whether conditions known to diminish cognitive control (e.g., alcohol intoxication) might exacerbate the influence of peer context on risky decision making. Finally, as a first step toward our ultimate goal of utilizing this research to improve the efficacy of risk-taking prevention programs, we are examining whether targeted training designed to promote earlier maturation of cognitive control skills might attenuate the influence of peers on adolescent decision making.

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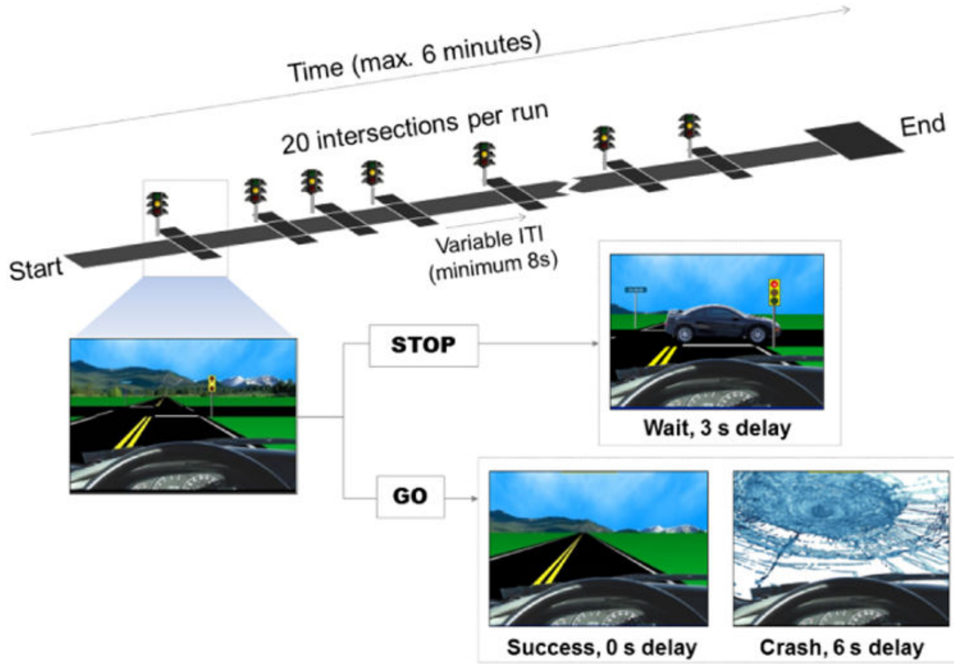

Figure 1. The Stoplight driving game

In the Stoplight driving game, participants are instructed to attempt to reach the end of a straight track as quickly as possible. At each of 20 intersections, participants render a decision to either stop the vehicle (STOP) or to take a risk and run the traffic light (GO). Stops result in a short delay. Successful risk taking results in no delay. Unsuccessful risk taking results in a crash, and a relatively long delay. Summary indices of risk taking include (a) the proportion of intersections in which the participant decides to run the light, and (b) the total number of crashes.

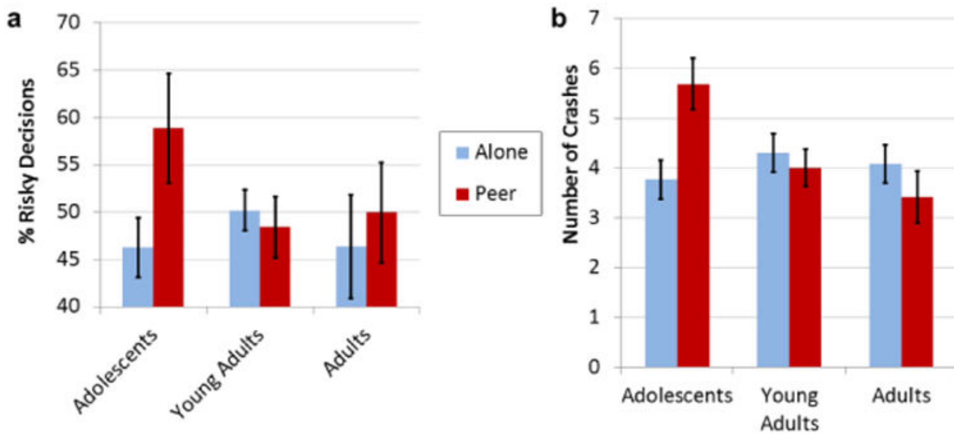

Figure 2. Differential susceptibility of adolescents to peer influences on Stoplight task performance

Mean (a) percentage of risky decisions and (b) number of crashes for adolescent, young adult, and adult participants when playing the Stoplight driving game either alone or with a peer audience. Error bars indicate the standard error of the mean.

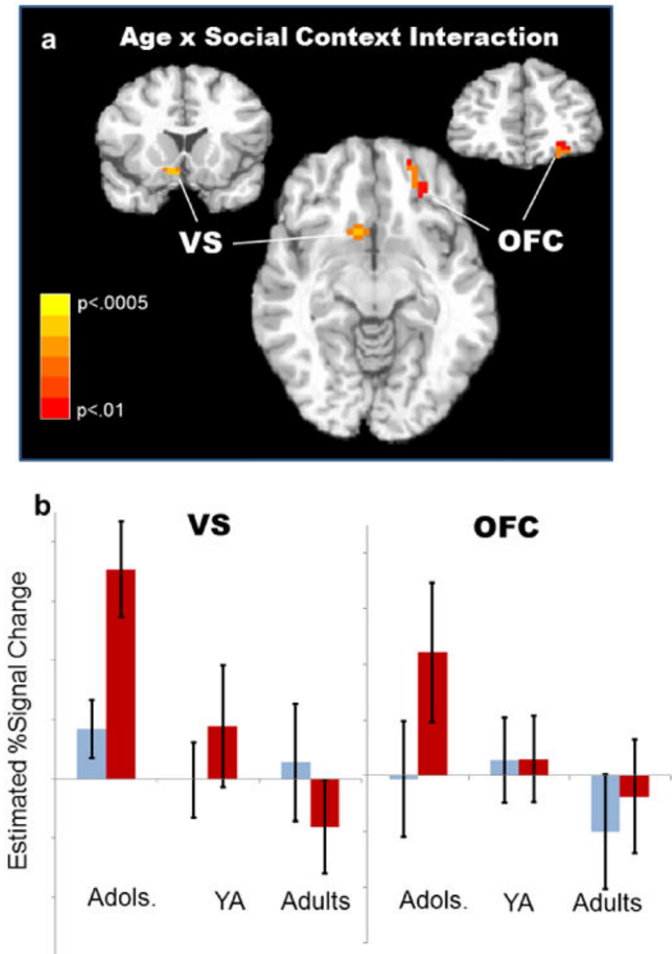

Figure 3. Brain regions showing an age by social condition interaction during Stoplight task performance

(a) Brain regions exhibiting an age by social condition interaction included the right ventral striatum (VS, MNI peak coordinates: x = 9, y = 12, z = -8) and left orgitofrontal cortex (OFC, MNI peak coordinates: x = -22, y = 47, z = -10). (b) Mean estimated BOLD signal change (beta coefficient) from the four peak voxels of the VS and the OFC in adolescents (adols.), young adults (YA), and adults under ALONE and PEER conditions. Error bars indicate standard errors of the mean. Brain images are shown by radiological convention (left on right), and thresholded at $p < .01$ for presentation purposes.

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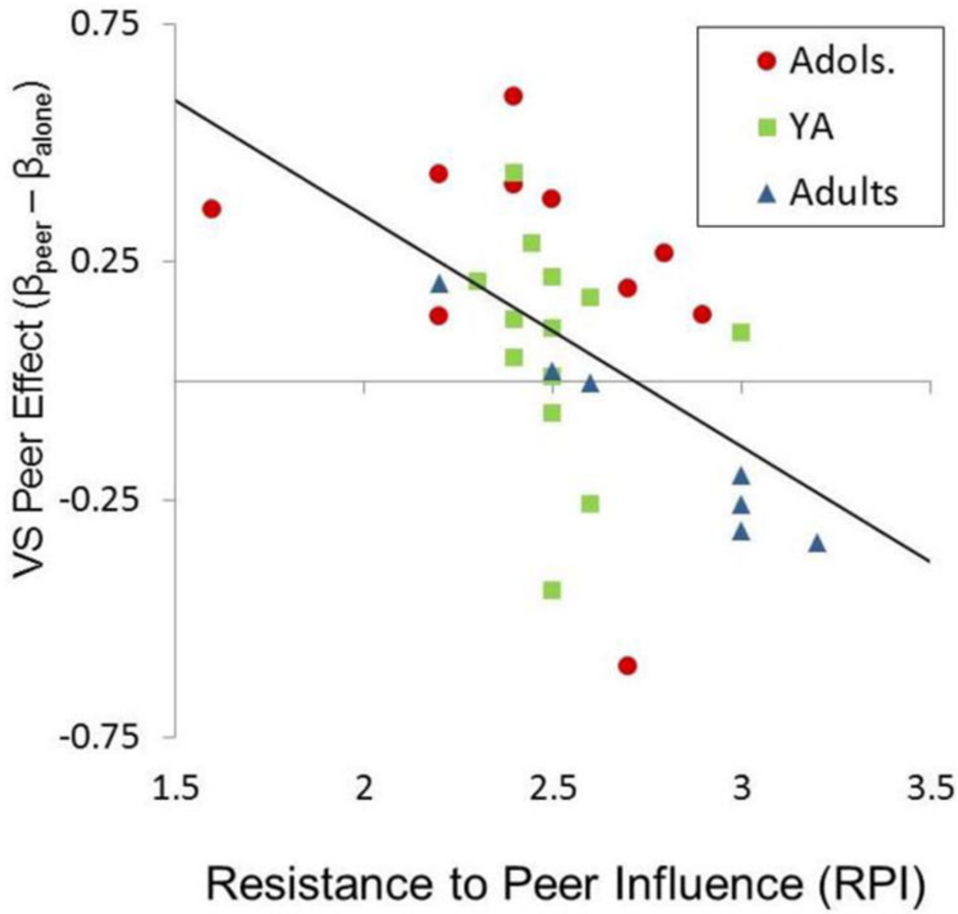

Figure 4. Behavioral and self-report correlates of Stoplight-related activity in the right ventral striatum (VS)

Resistance to Peer Influence correlated with Stoplight-related activity in the right ventral striatum (VS). Estimated activity was extracted from an average of the four peak voxels in the VS region of interest. Scatterplot of activity in the VS indicating an inverse linear correlation between self-reported resistance to peer influence (RPI) and the neural peer effect (i.e., the difference in average VS activity in peer relative to alone conditions, or βpeer − βalone).