

Modulation of meso-limbic reward processing by motivational tendencies in young adolescents and adults



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ABSTRACT

Adolescence is a particularly vulnerable period for the onset of substance use disorders and other psychopathology. Individual variability in motivational tendencies and temperament and significant changes in functional brain organization during adolescence are important factors to consider in the development of substance use and dependence. Recent conceptualizations suggest that sensitivity to reward is heightened in adolescence and that this motivation tendency may precipitate subsequent substance abuse. The present study examined the role of personality traits in mesolimbic neurobehavioral response on a monetary incentive delay (MID) task in young adolescents (11–14 years) and emerging adults (18–25 years) using functional magnetic resonance imaging. As a group, adolescents were not more sensitive to gains than losses compared to adults during either anticipatory and feedback phases; instead, compared to adults they showed less sensitivity to incentive magnitude in mesolimbic circuitry during anticipation and feedback stages. However, personality modulated this response such that adolescents high in impulsivity or low in avoidance tendencies showed greater gain sensitivity and adolescents high in avoidance showed greater loss sensitivity during cue anticipation. In adults, mesolimbic response was modulated by the impulsivity construct such that high-impulsive adults showed reduced magnitude sensitivity during both anticipation and feedback compared to low impulsive adults. The present findings suggest that impulsive personality significantly modulates mesolimbic reward response during both adolescence and adulthood but avoidance and approach tendencies also modulate this response in adolescents. Moreover, personality modulated incentive valence in adolescents but incentive magnitude in adults. Collectively, these findings suggest that mesolimbic reward circuitry function is modulated by somewhat different parameters in adolescence than in adulthood.

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Introduction

Individual differences in motivational tendencies and temperament are a major factor in risk for substance use and dependence. Individuals who exhibit strong approach motivation tendencies, like high sensation seeking, novelty seeking and reward dependence, or high impulsivity are more likely to experiment with drugs (Ball et al., 1994; Donohew et al., 1991), show greater sensitivity to the reinforcing or other behavioral effects of drugs and alcohol (Hutchison et al., 1999; White et al., 2006), and escalate into substance dependence (Galizio and Stein, 1983; Wills et al., 1994). Preclinical studies have also confirmed these patterns ((Bevins et al., 1997; Perry et al., 2005). In some conceptual frameworks, adolescents are viewed as higher on approach tendencies and impulsivity than either younger children or adults (Chambers et al., 2003). Approach- and impulsivity-related personality traits, together with measures of brain function or volume and early

experimentation with alcohol, are strong predictors of future binge drinking during adolescence (Whelan et al., 2014). Therefore, strong approach tendencies and impulsivity exhibited during adolescence can be a major risk factor for substance dependence.

One of the reasons proposed for high vulnerability to substance use during adolescence is that adolescents have drives similar to those of adults but they lack fully mature regulatory or behavioral inhibition system, as described in the dual-systems hypothesis of brain development (Chambers et al., 2003). The imbalance between robust activation of motivational systems and weaker activation of inhibition systems increases the likelihood of engaging in risky and dangerous behaviors. Behavioral activation and approach behaviors have been strongly linked to mesolimbic dopamine circuitry (Depue and Collins, 1999). Consequently, adolescents might be expected to exhibit stronger mesolimbic activation or weaker prefrontal activation than adults on reward-processing tasks or other behaviors that are associated with motivation and behavioral activation.

One task that has been used very successfully to engage the mesolimbic system is the monetary incentive delay task [MID; (Knutson et al., 2000a)]. Numerous functional magnetic resonance

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imaging (fMRI) studies in adults show robust and replicable activation in ventral and dorsal striatum as well as the thalamus and cortical regions. Each trial of the MID task is typically composed of three separate phases (Fig. 1): a cue or anticipation phase, a target or response phase, and a feedback or outcome phase. In the cue phase, a certain monetary amount is presented to the subject as an incentive to respond quickly to the target in the next phase. The monetary amount can be positive, negative or neutral (no consequences for responding fast enough or too slowly). Positive incentives mean that the subject earns the amount for correct (i.e., fast) responses or fails to earn that amount for incorrect (i.e., slow) responses during the target phase. Negative incentives mean that the subject avoids losing the amount for correct responses or incurs a loss for incorrect responses. The neutral condition has no consequences on earnings or losses.

Somewhat surprisingly, at least with respect to the dual systems hypothesis, adolescents do not necessarily show stronger MID activation than adults in mesolimbic circuitry. Although (Galvan et al., 2006) reported greater mesolimbic response in 13–17 year olds compared to adults or younger children (7 to 11 years) in a MID-like task, several other studies have reported reduced mesolimbic activation in adolescents compared to adults, or no differences ((Bjork et al., 2004b; Bjork et al., 2010b; Cho et al., 2013; Geier et al., 2010; Lamm et al., 2014; Vaidya et al., 2013). In fact, a longitudinal study of MID response from mid- (16 years of age) to late adolescence (20 years of age) also

reported reduced striatal response during mid-adolescence, especially for high incentive values, regardless of valence (Lamm et al., 2014). However, another longitudinal fMRI study (Heitzeg et al., 2014) reported that the nucleus accumbens response to rewards increased until mid-to-late adolescence, then declined after about age 20, but that study did not have a large sampling of the 16-to-20 year age range and the majority of the subjects were children of alcoholics. (Geier et al., 2010) designed an anti-saccade MID task so that cue assessment could be analyzed separately from response preparation. In that task, adolescents showed reduced ventral striatal activation for cue assessment, but enhanced activation for response preparation, compared to adults. Consequently, adolescents show enhanced mesolimbic response compared to adults in some studies, but this may depend on the particular task phase that is sampled.

Another potential explanation for the mixed findings in adolescents on the MID task is that individual differences in genetic risk and personality or temperament may modulate mesolimbic response. For example, mesolimbic responses on the MID task are weaker in individuals who low in inhibition (Guyer et al., 2006) or have a higher risk-taking bias (Schneider et al., 2012). People who are high in impulsivity show less differentiation in mesolimbic fMRI among small incentive values (Vaidya et al., 2013). In addition, youths and adults with ADHD (Hoogman et al., 2011; Plichta and Scheres, 2014; Scheres et al., 2007), adolescent smokers (Peters et al., 2011) and adolescent Met

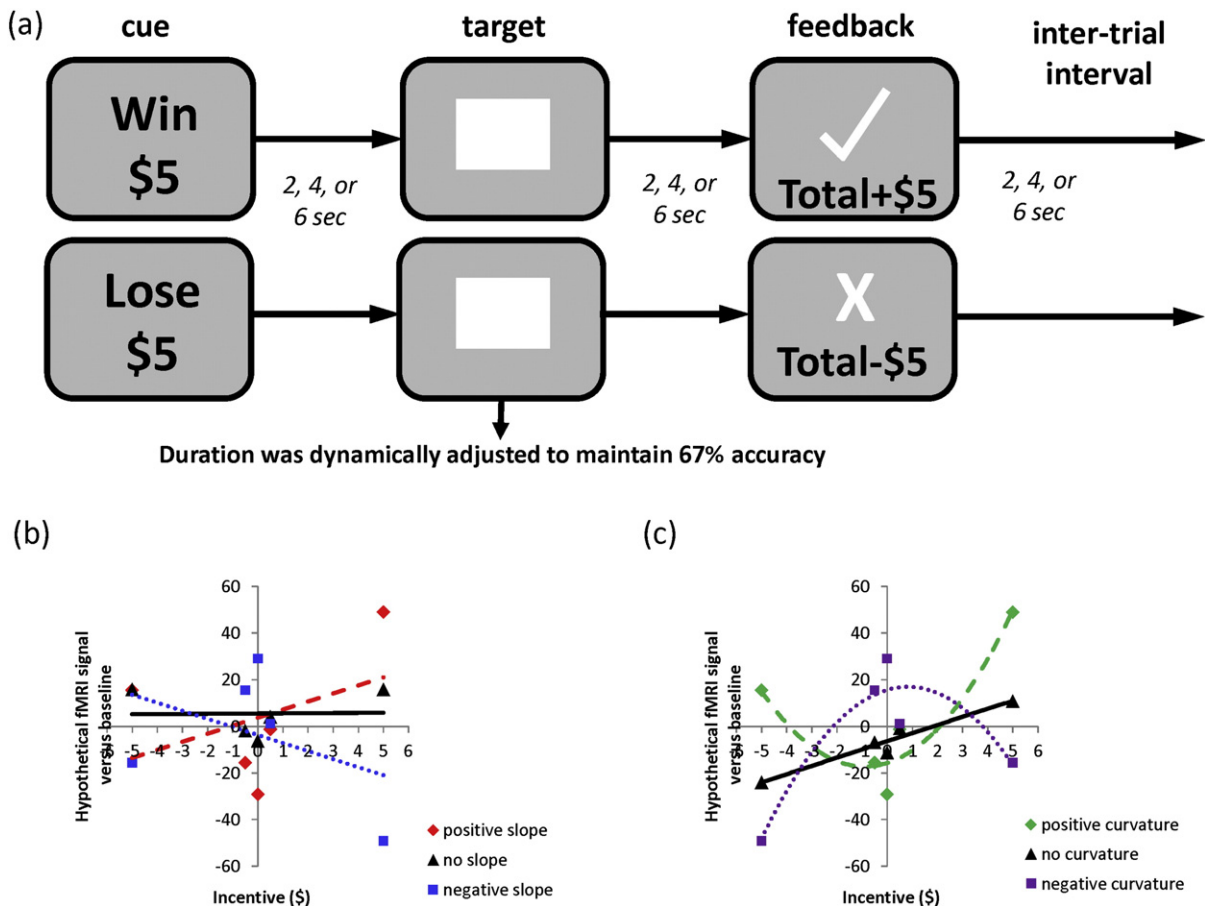


Fig. 1. (a) Monetary Incentive Delay task used in the present study. Participants could earn or lose money depending on speed of responding to a target stimulus (white rectangle). Each trial consisted of cue, target and feedback phases. The cue phase displayed a monetary value that could be won or lost. The target phase consisted of a simple stimulus presented briefly, and participants were instructed to respond within the duration of the target display (on the order of 250 ms). If the response time was less than the target duration a checkmark appeared on the feedback screen and the participant earned or avoided losing money. If the response time exceeded the target duration, an X appeared on the feedback screen and the participant did not win or incurred a loss of money. Across trials, the target display duration was adjusted to maintain trial accuracy at 67%. (b) The slope parameter indicates the slope of the linear component of a quadratic function fit to the fMRI signal in the different incentive conditions. A positive slope indicates greater fMRI response to positive incentive values and a negative slope indicates greater fMRI response to negative incentive values. (c) The curvature parameter indicates the degree of curvature of the quadratic function. A curvature value of 0 indicates no curvature; a positive curvature value indicates greater concavity and a negative curvature value indicates greater convexity. In other words, a more concave function would reflect greater fMRI signal for the extreme compared to small incentive values but a more convex function would reflect a greater fMRI signal for small values.

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