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Effects of psychosocial stress on psychophysiological activity during risky decision-making in male adolescents

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ABSTRACT

Adolescence is characterized by increases in both perceived stress and risk-taking, although the effects of stress on risk-sensitive decision-making have received little attention in adolescent groups. We report psychophysiological data from the healthy control group of a larger project examining neuroendocrine and neuropsychological function in boys with conduct disorder. The present analysis focussed on healthy male adolescents ($n = 66$) performing a decision-making task that involved selection between two wheel-of-fortune gambles. The task was completed in a neutral state, and again following a psychosocial stress induction that robustly increased salivary cortisol levels and baseline autonomic arousal. Task-related changes in electrodermal activity (EDA) and heart rate (HR) were monitored during the receipt of win and loss outcomes. On gamble choice, stress attenuated the difference in risk taking between the losses-only and wins-only trials (the 'reflection effect') and reduced risk-taking on one further gamble type (i.e. a stress × gamble type interaction). In the neutral condition, EDA and HR deceleration responses were significantly greater for losses compared to wins. This physiological differentiation of losses and wins was reduced under stress, with a significant attenuation of the HR deceleration response. In addition, higher trait impulsivity scores predicted reduced EDA differentiation of the outcomes, and reduced EDA stress reactivity. As a limitation, the order of neutral and stress sessions was not counterbalanced. Reduced psychophysiological discrimination between positive and negative outcomes may contribute to the effects of stress on risky decision-making in adolescents.

1. Introduction

Adolescence is a key period of onset for various forms of psychopathology (Fairchild, 2011), including mood disorders and addictive disorders (Merikangas et al., 2010). During this developmental phase, the levels of objective and perceived stress increase substantially (Galvan and McGlennen, 2012). It is also a critical phase in cognitive development in relation to incentive motivation and risk processing (Bjork et al., 2011; Blakemore and Robbins, 2012; Van Leijenhorst et al., 2010), driving an escalation in risky behaviors including reckless driving and risky sexual behavior (Dahl, 2004; Figner and Weber, 2011). Nevertheless, the interaction between stress and risky decision-making during adolescence is a neglected topic. In adult research, such as occupational settings, it is well-recognized that stress (manifested as either physiological arousal or subjective anxiety) exerts a profound influence on decision-making (Janis and Mann, 1977). Recent studies have sought to model these effects in the laboratory. Using a public speaking challenge (the Trier Social Stress Test; Kirschbaum et al., 1993) in adult groups, stress was shown to impair the acquisition of an advantageous strategy on the Iowa Gambling Task (Preston et al., 2007), and increased risk-taking on explicitly-stated win and loss probabilities in the Game of Dice task (Starcke et al., 2008). An alternative challenge, immersion of the hand in icy water (the cold pressor) was seen to enhance the "reflection effect" (Porcelli and Delgado, 2009), where risk-taking is typically greater for choices involving loss outcomes compared with choices involving gain outcomes (Tversky and Kahneman, 1981). This enhancement was proposed to derive from an increased reliance upon automatic, emotional systems under stress (Porcelli and Delgado, 2009).

Although these studies in adult groups collectively indicate an alteration of decision-making under stress, the direction of effect is inconsistent, as recognized in a systematic review of 17 studies by Starcke and Brand (2012). While some studies report an increase in risky choices under stress (Preston et al., 2007; Starcke et al., 2008), others report the opposite; for example, an experiment using the cold pressor in older adults reported reduced risk taking on a driving simulation task (Mather et al., 2009). Using a two-choice gambling task in student volunteers, the threat of electric shock reduced risk-taking compared

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to safe trials where shocks could not occur (Clark et al., 2012b). In our previous report investigating risky decision-making in healthy adolescents and adolescents with conduct disorder, there was reduced selection of risky gambles in both groups following a social competition-based stress induction (Fairchild et al., 2009).

A further issue is whether stress directly affects risk preferences (i.e. risk seeking or risk avoidance), or whether stress primarily modulates subcomponents feeding into the decision-making process, such as strategy use, control of automatic tendencies, and – of primary interest here – reactivity to rewarded or punished outcomes (Starcke and Brand, 2012). According to the Somatic Marker Hypothesis (Bechara and Damasio, 2005), the evaluation of risky alternatives involves re-activation of emotional memories at the level of the body, which help us to avoid options that have been penalized in the past. By directly engendering 'incidental' somatic arousal, acute stress may interfere with the detection of somatic markers attached to the decision, leading to disadvantageous choice (Preston et al., 2007). We note that this account could also predict increased conservative choice under stress, via a generalized tendency to evaluate all decision options as more risky.

Previous studies have characterized psychophysiological responses during decision-making tasks (Bechara et al., 1999; Crone et al., 2004; Goudriaan et al., 2006; Studer and Clark, 2011). However, earlier studies have not assessed the effects of stress on these signals. The main objective of the present investigation was to examine the impact of stress on physiological responses to win and loss outcomes on a Risky Choice Task. We analyzed previously unreported psychophysiology data (electrodermal activity and heart rate) from the healthy control group of a larger project involving boys with conduct disorder (Fairchild et al., 2008, 2009). Study participants performed a Risky Choice Task on two occasions, in a neutral state and following a stress induction. Previous reports from this project have described the cortisol responses to the stress procedure, and subsequent changes in choice behavior, in the groups with and without conduct disorder.

We considered the adolescent sample to be particularly appropriate for this question, as adolescence is likely to be a key phase for observing interactions between stress and risk-taking (Blakemore and Robbins, 2012). For example, in a cross-sectional design, higher levels of daily self-reported stress in 14–17 year olds predicted increased laboratory risk-taking (Galván and McGlennen, 2012). Comparing 'hot' and 'cold' versions of a risk-taking task (the Columbia Card Task), adolescents were more risky than adults in the emotional context, but did not differ in the non-emotional context (Figner et al., 2009). These studies indicate linkage between stress and risk-taking during adolescence. The use of a male sample was dictated by the focus of the larger project on conduct disorder, which is considerably more prevalent in boys (Moffitt et al., 2001).

The Risky Choice Task involved repeated selection between two wheel-of-fortune gambles, where one of the wheels varies systematically in the probability of winning/losing, the magnitude of available wins, and the magnitude of available losses (based on Rogers et al., 2003) (see Fig. 1). Two additional trial-types allowed measurement of the reflection effect. Variants of this task were sensitive to a range of pharmacological manipulations including tryptophan depletion (Murphy et al., 2009; Rogers et al., 2003), alcohol administration (George et al., 2005), and exogenous cortisol administration (Putman et al., 2010). For our analysis of psychophysiological responses, we focused on outcome-related activity, given that wins and losses impact reliably on both cardiovascular and electrodermal activity (EDA) (Bechara et al., 1999; Clark et al., 2012a; Studer and Clark, 2011). Decision-related activity was not modeled, given the short time-window that was available for gamble selection, coupled with the canonical time-courses for EDA and heart rate (HR) responses (Bradley and Lang, 2007).

A second, exploratory, aim was to examine individual differences in stress reactivity and outcome processing as a function of trait impulsivity. Impulsivity is linked to a range of addictive disorders that involve risky behavior (Verdejo-Garcia et al., 2008), and high trait impulsivity in the general population predicts elevated risk-taking (Franken et al., 2008; Kirby and Finch, 2010; Sweitzer et al., 2008). However, the relationship between impulsivity and stress reactivity has not been explored. Although stress exposure is robustly linked to relapse propensity in drug addiction (Sinha, 2008), the only study that has examined stress reactivity as a function of trait impulsivity found a *negative* relationship with the cardiac response to public speaking challenge (Allen et al., 2009). We sought to further examine these relationships between impulsivity, stress reactivity, and the physiological differentiation between win and loss outcomes.

2. Methods

2.1. Participants

We identified 66 participants in the healthy male adolescent control group from Fairchild et al. (2009) for whom psychophysiology data

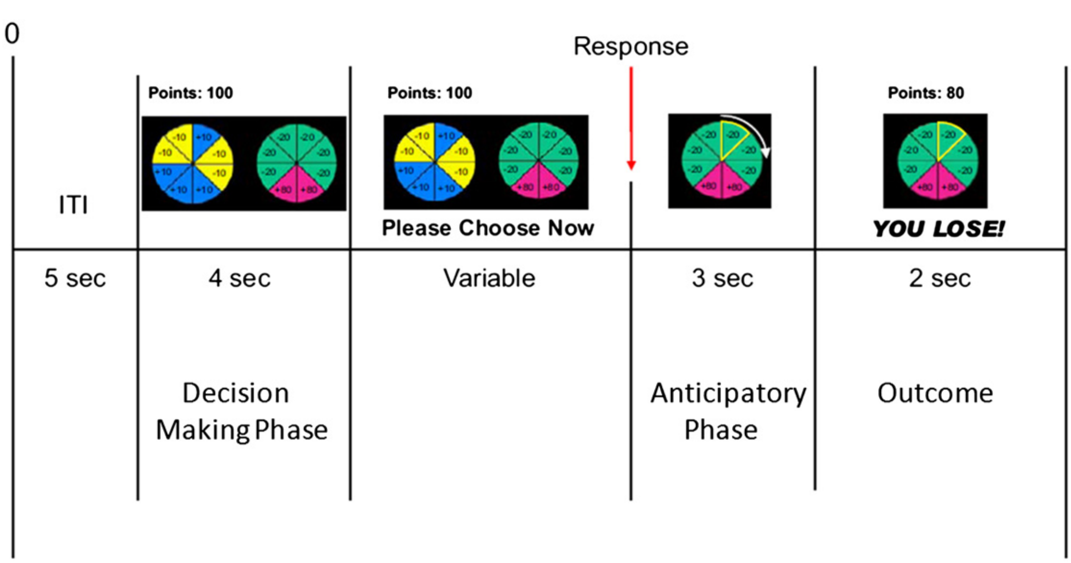

Fig. 1. Schematic representation of trial sequence timings for the Risky Choice Task. Following a 5 s ITI, two wheel options were presented for 4 s (choice phase), after which time participants were instructed to make a selection ("Choose Now"), for which no time limit was imposed. Next, a 3 s anticipatory phase was presented in which the chosen wheel was spun, before one of the wheel segments was highlighted to reveal the win or loss outcome for 2 s.