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Acute stress does not affect risky monetary decision-making

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ABSTRACT

The ubiquitous and intense nature of stress responses necessitate that we understand how they affect decision-making. Despite a number of studies examining risky decision-making under stress, it is as yet unclear whether and in what way stress alters the underlying processes that shape our choices. This is in part because previous studies have not separated and quantified dissociable valuation and decision-making processes that can affect choices of risky options, including risk attitudes, loss aversion, and choice consistency, among others. Here, in a large, fully-crossed two-day within-subjects design, we examined how acute stress alters risky decision-making. On each day, 120 participants completed either the cold pressor test or a control manipulation with equal probability, followed by a risky decision-making task. Stress responses were assessed with salivary cortisol. We fit an econometric model to choices that dissociated risk attitudes, loss aversion, and choice consistency using hierarchical Bayesian techniques to both pool data and allow heterogeneity in decision-making. Acute stress was found to have no effect on risk attitudes, loss aversion, or choice consistency, though participants did become more loss averse and more consistent on the second day relative to the first. In the context of an inconsistent previous literature on risk and acute stress, our findings provide strong and specific evidence that acute stress does not affect risk attitudes, loss aversion, or consistency in risky monetary decision-making.

1. Introduction

Because risky decisions are both ubiquitous and must often be made under stress, it is imperative to understand the interactions between stress and choices under risk. However, despite a number of studies examining acute stress and risky monetary decision-making (see Table S1), it is as yet unclear whether and how they interact. In the gain domain, several studies find evidence for more gambling[1] under acute stress (i.e. riskier choices; less risk aversion; more utility function convexity) (Preston et al., 2007; Starcke et al., 2008; Putman et al., 2010; Pabst et al., 2013b, 2013c), while others find *less* gambling under stress (i.e. safer choices; more risk aversion; more utility function concavity) (Porcelli and Delgado, 2009; Cingl and Cahlikova, 2013), no changes in gambling (von Dawans et al., 2012; Delaney et al., 2014; Kandasamy et al., 2014), or both more and less gambling depending on factors like gender (Lighthall et al., 2009; van den Bos et al., 2009), time (Pabst et al., 2013a), trait anxiety and depressive symptoms (Robinson et al., 2015), or outcome magnitude (von Helversen and Rieskamp, 2013). Even with respect to gender, the findings are equivocal: roughly equal numbers of studies found interactions with gender (Preston et al., 2007; Lighthall et al., 2009; van den Bos et al., 2009) as did not (Starcke et al., 2008; Pabst et al., 2013b; von Helversen and Rieskamp, 2013; Kandasamy et al., 2014).

One reason for this apparent inconsistency may be that, with one exception (Kandasamy et al., 2014; see Table S1), all the studies mentioned above used the same problematic measure of risky

Abbreviations: HPA, Hypothalamic-Pituitary-Adrenal; CPT, Cold Pressor Test; CI, Confidence Interval.

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[1] Risk attitudes are commonly represented by the curvature of the utility function (concave for gains, and convex for losses, a difference known as the reflection effect). This curvature leads to risk aversion for gains, and risk seeking for losses. More pronounced curvature entails more risk aversion for gains *and* more risk seeking for losses, while less curvature (more linearity) entails the opposite: less risk aversion for gains, and less risk seeking for losses. For legibility and for consistency with the extant literature, when we state "more gambling" and the like in this paper, we are referring to the gain domain unless specifically indicated otherwise, and we mean to imply the opposite for the loss domain.

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decision-making: a simple probability of gambling. This coarse measure is inadequate because choices between more and less risky options reflect the combined contributions of multiple different processes. For example, someone under stress might gamble less (that is, their probability of gambling might go down) because they dislike the element of chance or risk in the gamble (termed risk attitudes), because they overweight the risky loss relative to the risky gain (termed loss aversion), or simply because they are choosing more (or less) consistently than before despite having the same risk attitudes and loss aversion. Depending on the kinds of choices, other factors can also influence the probability of gambling, including probability weighting (the subjective, as opposed to objective, probability of an event occurring), ambiguity aversion (the distaste for unknown probabilities in decision options), or even dynamic updating when learning in complex, changing, or experiential settings.

Concluding that changes in the probability of gambling are due to changes in attitudes toward risk without dissociating other relevant processes would be analogous to concluding that stress affects memory recall after a study in which participants memorized items and performed a recognition test all while under stress. Such a conclusion would be obviously flawed as differences in recognition could reflect changes in perception, encoding, consolidation, familiarity, or recall – and without careful design and analysis, would all be thoroughly confounded. By the same token, the fundamentally different processes underlying risky choices must be simultaneously and separately quantified, or otherwise accounted for, in order to understand the ways in which acute stress does and does not affect decisions under risk.

In this study, we sought to dissociate and quantify three separable decision-making processes under acute stress in a fully-crossed within-subjects design. Briefly, participants came in on each of two days, identical except for experiencing an acute stress or control manipulation with equal probability on each day. Individual differences in HPA axis activity were objectively quantified with four measurements of salivary cortisol per day (Velasco et al., 1997; McRae et al., 2006). Participants' decision-making was also quantified with a risky decision-making task (Sokol-Hessner et al. 2009, 2013, 2015a, 2015b) that, in combination with an econometric model of valuation and decision-making, allowed the separation of risk attitudes, loss aversion, and consistency in decision-making for each participant on each day. Finally, statistically powerful hierarchical Bayesian analysis methods were used to pool the data from 120 participants, both leveraging individual differences and group-level analysis to identify how acute stress affects or spares the three measured processes contributing to risky decision-making.

2. Methods

2.1. Participants

A total of 122 participants completed the task. Two participants were subsequently dropped when it became apparent that they did not understand the mechanics of the task, leaving a total of 120 participants (64 female; mean age = 22.4, standard deviation = 4.5). Our fully crossed design (Stress or Control condition on each of Day 1 and Day 2) resulted in four groups (Stress-Stress, Stress-Control, Control-Stress, or Control-Control). Participants were evenly distributed (N = 30) across these four groups. One participant was excluded from cortisol analyses as their mean salivary cortisol level was more than thirty standard deviations above the group mean.

All participants provided informed consent in accordance with procedures approved by NYU's University Committee on Activities Involving Human Subjects.

2.2. Study design

2.2.1. Overall study design

All participants came in for two nearly identical sessions, separated by a mean of 5.3 days (standard deviation = 2.7; see Fig. 1; delay between sessions did not differ as a function of Group: $F(3,119) = 1.48$, $p = 0.22$). All sessions began between 11:30a.m. and 5:20p.m. (Day 1 mean = 2:17p.m., standard deviation = 1.6 h; Day 2 mean = 2:12p.m., standard deviation = 1.5 h). Following consent, participants were immediately endowed with $30 and told they would be paid the outcome of a subset of the trials in the decision-making task. The experimenter then read the task instructions out loud as the participant silently read along, after which participants completed a brief comprehension quiz on task details, and completed practice trials under experimenter supervision.

The first of four saliva samples was then taken (see below), after which participants underwent either the cold pressor test (CPT; a common acute stress induction procedure; Velasco et al., 1997; McRae et al., 2006) or a lukewarm water control. In the CPT, participants submerge their non-dominant arm up to and including their elbow in 0–4 °C water for three minutes. The participant is asked to not speak during the CPT, and the time elapsed is not shared with the participant. The lukewarm water control used 30–32 °C water. Participants had an equal chance of undergoing the CPT or control condition on each of the two days. Immediately following the conclusion of the CPT (or control), a second saliva sample was collected, and then participants were given an 8-min break during which they were asked to sit quietly without using any digital devices. They then gave a third saliva sample, after which they completed the risky decision-making task which took roughly 23 min (see below; Sokol-Hessner et al. 2009, 2013, 2015a, 2015b). Finally, participants gave a fourth saliva sample and completed a post-study questionnaire.

Participants were paid $15 per hour, plus their adjusted $30 endowment at the end of each day. Fifteen trials were selected at random from the task and their outcomes summed with the endowment to produce the adjusted endowment. The mean adjusted endowment at the end of Day 1 was $53.08 (standard deviation = $22.08), and Day 2 was $51.80 (standard deviation = $18.19). The difference in payment between days was not significant (paired samples *t*-test, $p = 0.62$).

2.2.2. Risky decision-making task

The main task of interest was a risky monetary decision-making task. As the task we used has been described in detail elsewhere (Sokol-Hessner et al., 2009, 2013), we will briefly summarize it here. Participants made 150 decisions between risky binary gambles and guaranteed alternatives. For 120 of the trials, termed "gain-loss trials", the risky gamble consisted of equal chances of winning some amount or losing a different amount (amounts varied trial-to-trial), versus a guaranteed alternative of zero dollars. In the remaining thirty "gain-only trials", the risky gamble yielded a positive amount or zero dollars with equal probability, and the guaranteed alternative was a smaller positive amount. The values used on each trial were unique (i.e. no trials were repeated). Trial order was random. The 50/50 probabilities used throughout the task effectively eliminated possible roles for ambiguity and probability weighting in the task, as all probabilities were explicitly known, and probabilities did not vary.

On each trial, the choice options were initially presented for 2s. After two seconds had passed, a response prompt ("?") appeared prompting participants to enter their choice within two seconds. This was followed by an inter-stimulus interval (1s), the display of