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Abstract
People's decisions are often susceptible to various demands exerted by the environment, leading to stressful conditions. Although a goal for researchers is to elucidate stress-coping mechanisms to facilitate decision-making processes, it is important to first understand the interaction between the state created by a stressful environment and how decisions are performed in such environments. The objective of this experiment was to probe the impact of exposure to acute stress on financial decision making and examine the particular influence of stress on decisions with a positive or negative valence. Participants' choices exhibited a stronger reflection effect when participants were under stress than when they were in the no-stress control phase. This suggests that stress modulates risk taking, potentially exacerbating behavioral bias in subsequent decision making. Consistent with dual-process approaches, decision makers fall back on automatized reactions to risk under the influence of disruptive stress.

People are often forced to make important decisions under stress (Janis, 1993). Stock-market brokers, for instance, make important financial decisions under extreme time constraints while experiencing excessive noise, heat, and antagonistic interpersonal interactions. Similarly, emergency-service personnel make life-saving decisions and perform drug-dose calculations under stress (Kozena & Frantik, 2001). One important question is whether stress might lead decision makers to take more risks or, alternatively, whether previously identified biases in risk taking, such as reflection effects (greater preference for risky options when decisions involve losses rather than gains; Kahneman & Tversky, 1979), might be exacerbated under stress. Dual-process approaches suggest that stressful conditions that interfere with rational, deliberative processes ought to cause decision-makers to fall back on more intuitive, automatic processes—exacerbating biases such as reflection effects (e.g., Evans, 2003; Kahneman & Frederick, 2002; Reyna, 2004).

Thus, the goal of this experiment was to examine the interaction between extrinsic acute stress (via the cold pressor task) and financial decision making (via gambles presented in either the loss or gain domain). Participants chose between two potentially negative outcomes (loss domain) or two potentially positive outcomes (gain domain) of equal expected value but varied probability, either under normal or stressful conditions. We hypothesized that stressed participants would exhibit increased risky behavior on loss-domain trials but increased conservatism on gain-domain trials, which is consistent with dual-process approaches.

EXPERIMENT 1

Method

Participants

Thirty-three participants were involved in the experiment. Final data analysis for the financial decision-making task was conducted on 27 of the 33 (13 females, 14 males; mean age = 21.08 years); 3 participants withdrew prior to completion, and 3 failed to meet task requirements by missing an excessive number of trials. Participants were Rutgers University, Newark, students who received research credit. Additionally, participants received performance-based compensation, the summed outcomes of a random gamble from each block ($0–$4.00).

Procedure

Participants completed four experimental blocks, each containing a recognition memory task and a financial decision-making task. During the recognition memory task, but prior to the financial decision-making task of each block, participants were exposed to either a no-stress control procedure (first two blocks) or extrinsic acute stress (last two blocks).

Stress Induction

Acute stress was induced by immersion of the participants' dominant hand in ice-cold water (4 °C) for 2 min. This procedure, known as the cold-pressor task, has an extensive history as an acute stressor (Ferracuti, Seri, Mattia, & Cruccu, 1994; Kelly, Ashleigh, & Beversdorf, 2007) and comprised our stress condition. A no-stress control condition required immersion of the participants' dominant hand in room-temperature water (25 °C) for 2 min.

Recognition Memory Task

Participants performed a recognition memory task as an additional manipulation check for stress induction, because the cold pressor has been found to influence memory performance (e.g., Kelly et al., 2007). Participants were presented with a unique list of 16 emotionally neutral words for 30 s followed by a 17-s fixation in a counterbalanced fashion. After the fixation, a recognition task was administered involving multiple 2-s presentations of studied and nonstudied words (12 total); each word was followed by a 4-s intertrial interval. This task was timed to allow for each participant's hand to be immersed in water for 2 min.

Financial Decision-Making Task

After the recognition memory task, participants performed a gambling task involving a choice between two alternatives of equal expected value, but varied probability. On a given trial, choices were presented in either the loss or gain domain: a possibility to “lose” or to “win” money, respectively. Two sets of gambles were used in both domains. In one set, participants faced a decision between an 80% chance of losing $0.75 and a 20% chance of losing $3.00 (loss domain; Fig. 1). In another trial, however, participants might be presented with an 80% chance of winning $0.75 or a 20% chance of winning $3.00(gain domain). A second set of gambles comprised a choice between a 60% chance of losing $1.00 and a 40% chance of losing $1.50; in another trial, participants were presented with a 60% chance of gaining $1.00 and a 40% chance of gaining $1.50. There were 160 trials during the experiment, 80 within each stress condition, 40 in each decision domain. Thus, 20 trials of each gamble type (60/40 vs. 80/20) were present within each stress and decision-domain condition. Although two different sets of gambles were included to provide variety for participants, data from both sets were collapsed within a domain during analysis. Feedback was presented as a confirmation of the dollar amount of their loss or gain or a statement that they lost or gained $0.00.

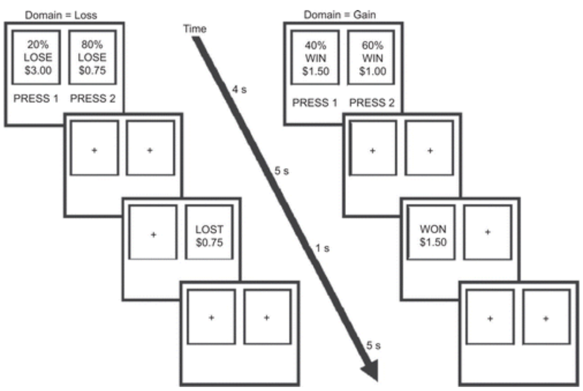

Fig. 1. Illustration of the two sets of gambles (of equal expected value) used in the financial decision-making task. In the example from the first set (left), the participant must choose between an 80% chance of losing $0.75 and a 20% chance of losing $3.00. In the example from the second set (right), the participant must choose between a 60% chance of winning $1.00 and a 40% chance of winning $1.50. Although in these examples the gamble from the first set is in the loss domain and the gamble from the second set is in the gain domain, both domains were represented equally often in each set over the course of the experiment. Participants had 4 s to process the gamble and make a decision. After a 5-s fixation, the outcome of their choice was presented for 1 s, and another 5-s fixation followed.

Behavioral Measures

Choosing the option associated with a lower probability was considered a risky choice, whereas choosing the higher probability option was deemed a conservative choice. This framework allowed us to test the interaction between independent variables of interest, namely individuals' physiological state (no-stress vs. stress) and decision domain (loss vs. gain), and the dependent variable of participants' chosen decision-making strategy (risky vs. conservative).

Skin conductance levels (SCLs) were acquired throughout the experiment, allowing for probing of physiological states during stress and no-stress conditions. A BIOPAC conductance module and AcqKnowledge software were used to collect and analyze data. SCLs were computed as the average level of skin conductance (in microsiemens, µs) over the entire financial decision-making task. Data were normalized using a square-root transform (Levey, 1980).

Results

Effect of the Acute Stress Induction

To assess the efficacy of the stress induction procedure, we measured SCL during each block of the financial decision-making task. The SCL waveform was averaged within each stress condition to compare between stress and no-stress blocks. A paired *t* test revealed significantly elevated SCL in the stress compared to the no-stress condition, $t(26) = 5.50$, $p < .001$, $p_{rep} = .986$, $d = 0.28$ (Fig. 2), suggesting that decision making occurred under stress. Furthermore, a one-sample *t* test (vs. chance) indicated elevated subjective stress ratings, $t(26) = 4.14$, $p < .01$, $p_{rep} = .986$, $d = 0.80$.

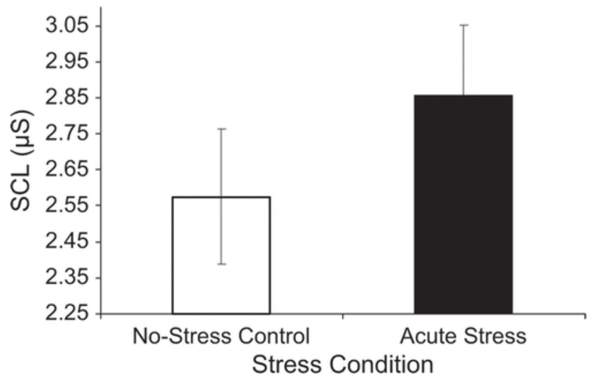

Fig. 2. Comparison of the average skin conductance level (SCL) waveform (in transformed microsiemens) during the entire financial decision-making task, as a function of condition (no stress vs. acute stress). Error bars show 1 *SEM*.

Effects of Acute Stress on the Recognition Memory Task

A paired *t* test indicated that participants' accuracy on the recognition memory task was significantly worse under stress ($M = 0.80$, $SD = 0.08$) than under no stress ($M = 0.87$, $SD = 0.11$), $t(26) = -2.96$, $p < .01$, $p_{rep} = .959$, $d = -0.74$. These results support the efficacy of the cold pressor task, suggesting that stress had detrimental effects on cognitive performance in this task.

Effects of Acute Stress on Financial Decision Making

To examine the effect of acute stress on financial decision making, a 2 (stress condition: no stress vs. acute stress) × 2 (decision domain condition: loss vs. gain) repeated measures analysis of variance (ANOVA) was conducted on strategy-choice data (risky vs. conservative). These data were computed as the proportion of times a participant made risky or conservative choices in each Stress × Decision domain condition, compared to the total number of available choices (with null trials removed). The proportion of risky choices and the proportion of conservative choices within a condition summed to 1, so analyses were conducted on risky-choice data only. A significant main effect of decision domain was observed, $F(1, 26) = 20.41$, $p < .001$, $p_{rep} = .986$, $\eta_P^2 = .440$. Post hoc one-tailed *t* tests indicated that participants in the no-stress condition made significantly more risky choices in the loss domain than in the gain domain, $t(26) = 2.85$, $p < .01$, $p_{rep} = .970$, $d = 1.22$. Thus, reflection was observed in participants' decision making.

Most interesting was the two-way interaction between stress and decision domain on risk taking, $F(1, 26) = 6.40$, $p < .05$, $p_{rep} = .938$, $\eta_P^2 = .197$. Significantly fewer risky decisions (i.e., increased conservatism) were made on gain-domain trials under acute stress as compared to no stress, $t(26) = -2.574$, $p < .01$, $p_{rep} = .956$, $d = -0.45$ (see Fig. 3). On loss-domain trials, participants showed a trend toward making a higher number of risky decisions under acute stress than under no stress, $t(26) = 1.55$, $p < .10$, $p_{rep} = .856$, $d = 0.26$. These results indicate that acute stress exaggerates the reflection effect.

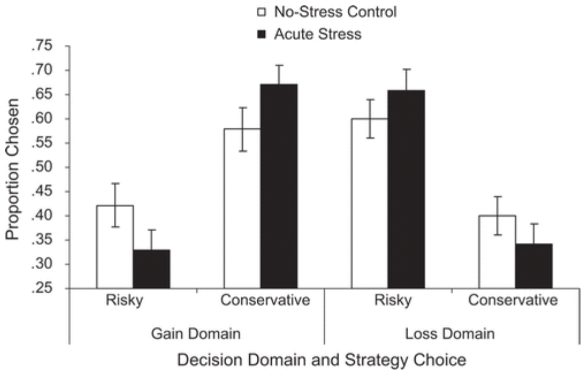

Fig. 3. Proportion of participants' risky and conservative strategy choices in Experiment 1 as a function of domain (loss or gain domain) and condition (no stress vs. acute stress). Although analyses were conducted only on risky choices, data on both risky and conservative choices are presented for completeness. Error bars show 1 *SEM*.

Collapsing across decision-making strategy, a 2 (no stress vs. acute stress) × 2 (loss vs. gain) repeated measures ANOVA was performed on reaction time data. A significant ordinal interaction was observed, $F(1, 26) = 10.65$, $p < .01$, $p_{rep} = .974$, $\eta_P^2 = .290$. Under no stress, participants performed significantly faster on gain as compared to loss trials. Notably, acute stress led to faster overall performance with roughly equivalent speed on gain and loss trials.

EXPERIMENT 2

One potential confound in this design concerns the lack of counterbalancing of stress administration. Although this was intended as a precaution against the lingering effects of stress, it could potentially lead to practice effects at the within-subjects level. To address this concern, we conducted a similar experiment without the application of stress. Our reasoning was that if the original result showing increased reflection was due to practice, we should see a similar effect of time on strategy choices in this second experiment between its first and second halves (the critical point at which the stress conditions switched from no stress to stress in Experiment 1).

Method

Twenty-one participants were involved in this experiment (11 females, 10 males; mean age = 20.1 years). The procedure used in Experiment 2 was identical to that of Experiment 1, except that participants were only exposed to the no-stress control procedure.

Results

A 2 (first half: blocks 1 and 2 vs. second half: blocks 3 and 4) × 2 (decision domain condition: loss vs. gain) repeated measures ANOVA was performed on strategy-choice data. Behavior was divided along the midpoint of the experiment, where stress was induced in Experiment 1. Analysis yielded a significant main effect of decision domain on strategy, along the lines of the reflection effect. Participants made significantly more risky choices on loss trials than on gain trials, $F(1, 20) = 6.84$, $p < .05$, $p_{rep} = .933$, $\eta_P^2 = .255$. However, as was hypothesized, there was no effect of order on risky strategy choices, $F(1, 20) = 0.72$, $p > .05$, $p_{rep} = .566$, $\eta_P^2 = .035$, and no significant interaction was observed, $F(1, 20) = 0.94$, $p > .05$, $p_{rep} = .611$, $\eta_P^2 = .045$ (Fig. 4). A one-sample *t* test (vs. chance) indicated decreased subjective stress ratings, $t(20) = -8.35$, $p < .01$, $p_{rep} = .986$, $d = -1.82$. Interestingly, participants showed a facilitation of recognition memory between the first ($M = 0.88$, $SD = 0.08$) and second ($M = 0.92$, $SD = 0.06$) halves, the opposite of the original stress effect, $t(20) = 2.23$, $p < .05$, $p_{rep} = .895$, $d = 0.61$.

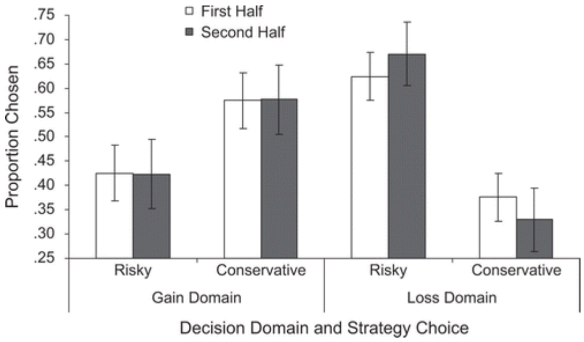

Fig. 4. Proportion of participants' risky and conservative strategy choices in Experiment 2 as a function of domain (loss vs. gain) and phase of the experiment. The first half of the experiment was equivalent to the no-stress condition in Experiment 1; the second half of the experiment was equivalent to the acute-stress condition in Experiment 1. Error bars show 1 *SEM*.

DISCUSSION

This study showed that extrinsic acute stress altered decision making by modulating risk taking. Specifically, we observed that the reflection effect—where people make risky decisions in the loss domain but conservative decisions in the gain domain—was significantly increased under stress. Consistent with dual-process approaches, it may be that, under stress, people come to rely more heavily on automatized risk biases—exacerbating already prevalent domain-dependent decision-making preferences. If stress interferes with processing resources required by the brain's executive systems, it is plausible that this would lead to an exaggerated reliance on lower-level automatized systems (Masicampo & Baumeister, 2008). This hypothesis is supported by stressed participants' poor performance on the recognition memory task, their reaction time data, and previous work on stress and executive-processes interactions (al'Absi, Hugdahl, & Lovallo, 2002; Hoffman & al'Absi, 2003).

A limitation of Experiment 1 was that the order of presentation for the stress conditions was not counterbalanced. Multiple researchers have observed immediate and sustained cortisol increases after exposure to cold stress (e.g., McRae et al., 2006; Washington, Gibson, & Helme, 2000). Therefore, counterbalancing was not performed so as to prevent stress from influencing subsequent blocks of trials. Experiment 2 was designed to address the possibility of a practice effect confounding the results of Experiment 1. In Experiment 2, participants performed the same task as in Experiment 1 after exposure to *only* a no-stress control procedure. Within-subjects comparisons of choice behavior indicate that strategy did not differ as a function of time. The results of Experiment 2 lend support to the results of Experiment 1 by indicating that no practice effect was present.

The current findings have implications for understanding how a person's environment might interfere with his or her ability to make decisions. If domain-dependent risk-taking biases are exaggerated under stress, decision makers might become unreliable due to typical life stress (i.e., job stress related to their profession). Even the use of neuroimaging technologies might be stressful. Magnetic resonance imaging can be loud and frightening for some individuals (Raz et al., 2005). Such stress might inadvertently produce more biased behavior, compared to behavior elicited out of the scanner environment.

Whereas responses to acute stress may have evolutionarily adaptive value overall, higher-order cognition may be compromised by relying on intuitive processes in response to stress. The current experiment identifies a stress-induced exaggeration of risk taking manifested as an increase in the reflection effect. Future research, however, must focus on identifying exactly how this occurs (e.g., affecting the value function, the decision weight function, or some other mechanism). Additionally, research may probe the use of cognitive techniques, such as emotion regulation strategies (Gross, 2002), as a way to overcome increased biases in risk taking resulting from stress. Such techniques, once developed, could be useful to those people working or living under extreme stress.

Acknowledgements

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