The impact of stress on financial decision-making varies as a function of depression and anxiety symptoms

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Stress can precipitate the onset of mood and anxiety disorders. This may occur, at least in part, via a modulatory effect of stress on decision-making. Some individuals are, however, more resilient to the effects of stress than others. The mechanisms underlying such vulnerability differences are nevertheless unknown. In this study we attempted to begin quantifying individual differences in vulnerability by exploring the effect of experimentally induced stress on decision-making. Threat of unpredictable shock was used to induce stress in healthy volunteers (N=47) using a within-subjects, within-session design, and its impact on a financial decision-making task (the Iowa Gambling Task) was assessed alongside anxious and depressive symptomatology. As expected, participants learned to select advantageous decks and avoid disadvantageous decks. Importantly, we found that stress provoked a pattern of harm-avoidant behaviour (decreased selection of disadvantageous decks) in individuals with low levels of trait anxiety. By contrast, individuals with high trait anxiety demonstrated the opposite pattern: stress-induced risk-seeking (increased selection of disadvantageous decks). These contrasting influences of stress depending on mood and anxiety symptoms might provide insight into vulnerability to common mental illness. In particular, we speculate that those who adopt a more harm-avoidant strategy may be better able to regulate their exposure to further environmental stress, reducing their susceptibility to mood and anxiety disorders. The threat of shock paradigm we employed might therefore hold promise as a 'stress-test' for determining individual vulnerability to mood and anxiety disorders.

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Introduction

It is well established that stress can precipitate mood and anxiety disorders (de Kloet et al., 2005). However, it is also recognised that there exist great differences amongst individuals; some individuals are resilient to stress, whilst others are particularly vulnerable (Kendler et al., 2004). However, the neural and behavioural mechanisms underlying such individual differences in vulnerability remain poorly understood. One potential mechanism by which stress might contribute to mood disorder vulnerability is via its modulatory impacts on behaviour (Dias-Ferreira et al., 2009, Robinson et al., 2013). In this study we sought to explore how the impact of stress on behaviour might vary as a function of individual differences in mood and anxiety symptoms.

We explored the impact of stress on performance of a well-validated financial decision-making paradigm: the Iowa gambling task (Bechara et al., 1994). In this task, healthy individuals learn to play from 'advantageous' decks of cards – which result in net gains across repeated selections – and to avoid 'disadvantageous' decks, which result in net losses (Maia and McClelland, 2004). To induce stress during this task we used the within-subject, within-session, threat of unpredictable shock paradigm, which has been shown to increase reliably the psychological, physiological and neural concomitants of anxiety, in both humans and experimental animals (Robinson et al., 2013, Schmitz and Grillon, 2012, Grillon, 2008). To explore individual differences in stress reactivity we recruited a sample of individuals self-identifying as healthy but reporting a range of trait anxiety and depression scores.

A small amount of prior work has explored the influence of stress on this task. Social stress - induced by threat of unprepared public speaking on the Trier social stress test - has been reported to reverse the adaptive bias towards advantageous decks, triggering increased selection of disadvantageous decks (Preston et al., 2007, van den Bos et al., 2009). Other work has shown that individuals at risk of anxiety disorders (Miu et al., 2008), depressed individuals (Must et al., 2013) and individuals with chronic pain (Walteros et al., 2011) also show an attenuation of this adaptive bias due to increased selection of disadvantageous decks. However, others reported *reduced* selection of disadvantageous decks in individuals with high trait anxiety (Mueller et al., 2010, Werner et al., 2009). What might underlie these discrepancies is unclear. Given the critical interplay between trait vulnerability and environmental stress in stress-diathesis models of mood and anxiety disorders (Kendler et al., 2004), it is important to understand the degree to which vulnerability and response to stress interact to influence decision making behaviour.

Based on prior results, we predicted that our healthy sample as a whole would demonstrate a bias towards avoiding disadvantageous decks at baseline (Bechara et al., 1994, Maia and McClelland, 2004), and that this bias would increase under threat of shock (Preston et al., 2007, van den Bos et al., 2009). In our key exploratory analysis we also examined the interaction between stress and mood/anxiety symptoms on task performance. Based on epidemiological evidence for increased pathological mood/anxiety symptoms following stress in vulnerable individuals (Kendler et al., 2004) and prior reports of greater disadvantageous deck selection in individuals with anxious and depressive symptomatology (Miu et al., 2008, Must et al., 2013), we predicted that individuals with high trait vulnerability would exhibit maladaptive responses to stress, resulting in a reduction in the bias towards selecting advantageous decks.

Methods

Participants

Forty-seven participants completed the experiment (31 female: 16 male; mean age=22.8, s.d.=4.23). Ethical approval was obtained from the UCL Research Ethics Committee (1764/001). Participants were recruited via responses to an advertisement through the UCL Institute of Cognitive Neuroscience Subject Database and provided written informed consent. All subjects completed a screening form in which they reported that they were healthy with no history of psychiatric, neurological or cardiovascular diagnosis.

Procedure

Stress was induced by unpredictable electrical shocks delivered using a Digitimer DS7A Constant Current Stimulator (Digitimer Ltd., Welwyn Garden City, UK), with an electrode secured to the wrist. A shock work-up procedure standardised the level of shock for each individual. During the threat block the screen was red and displayed a message "YOU ARE NOW AT RISK OF SHOCK" whereas in the safe block the screen was blue with the message "YOU ARE NOW SAFE FROM SHOCK". Participants were informed that shocks would only occur in the threat block, and that the shocks administered would be unpredictable and independent of their behaviour on the task. At the end of each block, participants indicated how anxious they had felt during each the threat and safe conditions on a scale from 1 ("not at all") to 10 ("very much so"). Participants also provided self-report measures of depression (Beck Depression Inventory; BDI) (Beck and Steer, 1987) and trait anxiety (State Trait Anxiety Inventory: STAI) (Spielberger et al., 1970).

Iowa Gambling Task

We adopted a forced-choice version of the Iowa Gambling task which enabled us to explore choice behaviour for all conditions (Cauffman et al., 2010). On each trial, one of four decks of cards was highlighted at random by a yellow border, and the participant had to choose whether to play or pass that deck. If they chose to play, the participant was shown a monetary outcome (win, loss or no change), and a running monetary total displayed on-screen changed accordingly. If they passed, the next deck was selected (with no change in the monetary total). If no response was made within 4 seconds the card was passed automatically. The probabilities and magnitudes of win and loss outcomes varied between decks such that two of the decks provided a net monetary gain on average if played repeatedly (advantageous decks), while the other two decks provided a net loss (disadvantageous decks). Participants played the game twice, once under threat of shock and once while safe (order counterbalanced) starting with new decks and a hypothetical $2,000 total in each of these two blocks. Each block consisted of 120 trials. Two shocks were delivered during the threat block (after the 13th and 58th trials).

Analysis

Choice behaviour and reaction times were analysed using SPSS version 22 (IBM Corp, Armonk, NY). Data from the two advantageous and the two disadvantageous decks were pooled prior to analysis resulting in two choice variables. Choice behaviour (proportion of cards accepted) was then analysed in 3-way deck (advantageous, disadvantageous) x stress (threat, safe) x symptom (depression/trait anxiety as a continuous variable, in separate analyses) ANCOVAs. Post-hoc analyses were performed using Pearson's r correlations between symptom measures and a measure of the impact of threat on choice (threat minus safe). Reaction time data were analysed in four-way deck (advantageous, disadvantageous) x stress (threat, safe) x decision (play, pass) x symptom (depression/trait anxiety as a continuous measure) ANCOVAs. Note that only N=42 participants could be included in the reaction-time analysis as 5 never played one or more of the decks and thus had incomplete reaction time data. Trait anxiety (mean = 41, a range = 21-64, standard deviation = 11) was normally distributed (Shapiro-Wilk test, p=0.28), but BDI (mean = 6, range = 0-26, standard deviation = 6) was skewed towards lower values (Shapiro-Wilk test, p<0.001) so a square root transformation was applied prior to analysis. For all analyses P=0.05 was considered significant. Based on the meta-analytic effect size of -0.58 for the Iowa gambling task (Mukherjee and Kable, 2014), t-test analysis in our sample (N=41) has an ~84% power to detect an effect size of alpha 0.01 (two-tailed)

Results

Individual differences and manipulation check

There was a strong correlation between depression and trait anxiety measures ($r(47)=0.74$, $p<0.0001$).

Subjects rated themselves as significantly more anxious ($F(1,46)=85.3$, $p<0.0001$, $\eta2=0.65$) during the threat condition (mean = 4.7/10, standard deviation = 2.3) than the safe condition (mean = 1.8/10, standard deviation = 1.2). This was not influenced by trait anxiety ($F(1,45)=0.004$, $p=0.95$, $\eta2=0.00009$) or depression ($F(1,45)=0.42$, $p=0.52$, $\eta2=0.009$).

Choice behaviour

We found a significant main effect of deck type (greater selection of advantageous decks: $F(1,46)=36.2$, $p<0.001$, $\eta2=0.44$) but no stress by deck interaction ($F(1,46)=0.43$, $p=0.51$, $\eta2=0.009$; **Table 1**). However, including trait anxiety in the model revealed a significant stress x deck x trait anxiety interaction ($F(1,45)=6.4$, $p=0.015$, $\eta2=0.13$) which was driven by a significant correlation between trait anxiety and stress-triggered propensity to play disadvantageous decks ($r(47)=0.336$, $p=0.021$) but not advantageous decks ($r(47)=-0.065$,$p=0.66$; significant difference between correlations: Steiger's $Z=1.96$, $p=0.05$). In other words, we observed (along a continuum) stress-potentiated harm-avoidance in individuals with no/low anxiety symptoms, but the opposite pattern - stress-potentiated risk-seeking - in individuals with moderate anxiety symptomatology (**Figure 2**). This was seen in the absence of a trait anxiety x deck interaction ($F(1,45)=1.1$,$p=0.31$).

Substituting trait anxiety for BDI in the model revealed a similar pattern of results. Critically, the significant stress x deck x depression interaction ($F(1,45)=8.9$, $p=0.005$, $\eta2=0.17$) was also driven by a significant correlation between depression scores and threat-potentiated task performance for disadvantageous decks ($r(47)=0.415$,$p=0.004$) but not advantageous decks ($r(47)= -0.012$, $p=0.94$; significant difference between correlations: Steiger's $Z=-2.1$, $p=0.03$; **Figure 2**). Again, no depression x deck interaction was seen ($F(1,45)=1.3$,$p=0.27$).

Including both trait anxiety and depression scores in the same model resulted in the symptom x diagnosis x deck interactions becoming non-significant (depression, p<0.12; anxiety, p<0.57) indicating that the two scales account for the same variance in this sample.

Reaction times

Subjects were faster to play than to pass cards ($F(1,41)=26$, $p<0.001$, $\eta^2=0.39$) but there was no main effect of stress ($F(1,41)=0.008$, $p=0.93$, $\eta^2<0.001$) deck ($F(1,41)=0.33$, $p=0.56$, $\eta^2=0.008$) or stress x deck interaction ($F(1,41)=0.004$, $p=0.95$, $\eta^2<0.001$; **Table 1**). Including symptoms in the model revealed no stress x deck x trait anxiety interaction ($F(1,40)=0.256$ $p=0.62$, $\eta^2=0.006$) or stress x deck x depression interaction ($F(1,40)=0.02$, $p=0.89$, $\eta^2<0.001$).

Discussion

The current study demonstrates an interaction between sub-clinical mood/anxiety symptoms and stress-responses on decision-making behaviour. Specifically, we found opposite stress-responses in those with low - versus those with moderate- anxiety and depression symptoms. On the one hand, individuals with low depressive symptoms displayed a pattern of stress-potentiated *harm-avoidance*, whilst those with moderate symptoms show an opposing pattern of stress-potentiated *risk-seeking*.

We replicated the frequently reported pattern of harm avoidance on the IGT across our sample as a whole (Maia and McClelland, 2004). Specifically, across all individuals, we saw a pattern of increased selection of advantageous over disadvantageous decks. The present study extends this, however, to show that in individuals with low depression or anxiety symptomatology this harm avoidance strategy is *increased* by stress. That is to say, these individuals are even more likely to avoid risky decks under the stress condition relative to baseline. This harm avoidant behaviour may therefore be adaptive. Specifically, in conditions of threat, it may be wise to seek to minimise further loss. On the IGT this leads to fewer negative outcomes which, in a naturalistic setting, might mitigate the negative impacts of stress. One possibility, therefore, is that this pattern of stress-induced harm-avoidance and reduced anxious/depressive symptomatology is causally linked. Those who respond in a more harm-avoidant manner to stress might be better at regulating their environmental exposure to sources of stress, and ultimately reduce their vulnerability to mood and anxiety disorders.

By contrast, in individuals with moderate symptomatology, the opposite pattern was evident. Stress provoked a pattern of increased risk-seeking as indexed by greater selection of disadvantageous decks under stress. This pattern has been observed in individuals with high mood and anxiety disorder symptomatology (Must et al., 2013, Walteros et al., 2011, Miu et al., 2008), and in response to social stress (Walteros et al., 2011, Werner et al., 2009). Here we extend and integrate these findings to show that this effect is specific to stress-response in symptomatic individuals. On the one hand, this response can be seen as maladaptive. Subjects appear to be seeking risk, which on average will lead to increased losses on this task, potentially increasing stress exposure in a vicious cycle. On the other hand this might simply reflect an alternative, albeit more risky, strategy. The disadvantageous decks do actually demonstrate larger occasional gains (as well as losses). So if a player is lucky, they could potentially more rapidly improve their overall gains, especially if they only occasionally sample from the risky decks. However, in the long run, this strategy will not pay off on the present task and will lead to increased overall losses. This alternative strategy may therefore drive elevated susceptibility to pathological symptoms; the more likely an individual is to adopt risky strategies, the more vulnerable they are to negative outcomes, associated negative mood states, and hence mood and anxiety disorders. Indeed, there is some naturalistic evidence for such a mechanism. Some individuals with high levels of social anxiety demonstrate high levels of risk-taking behaviour on questionnaire measures (Kashdan et al., 2006, Kashdan et al., 2008, Kashdan and McKnight, 2010). This may, in turn, explain some of the discrepancies across prior studies. Trait anxiety, for instance, has been shown to be associated with harm-avoidant behaviour on the Iowa gambling task in some studies (Mueller et al., 2010) and an opposite pattern of risk-seeking in other studies (Miu et al., 2008). Taking into consideration a given subject's current stress levels may go some way towards explaining this apparent variability.

It should be noted that the effect we see exists along a continuum. It is not that there are two different states; a harm avoidant and a risk-seeking behavioural state. Rather, the stress-induced behaviour varies as a function of symptoms, with some individuals in the middle showing no behavioural change at all. This is consistent with contemporary approaches to mental illness arguing that psychiatric disorders are continuous and not discrete states (Cuthbert and Insel, 2013). Moreover, these findings raise the possibility of using this stress manipulation as a screen for risk for common mental health problems. Specifically, it might be possible to develop an emotional 'stress-test' to probe individual differences in stress-responding in a controlled laboratory environment prior to the onset of a disorder. Future work will explore this possibility.

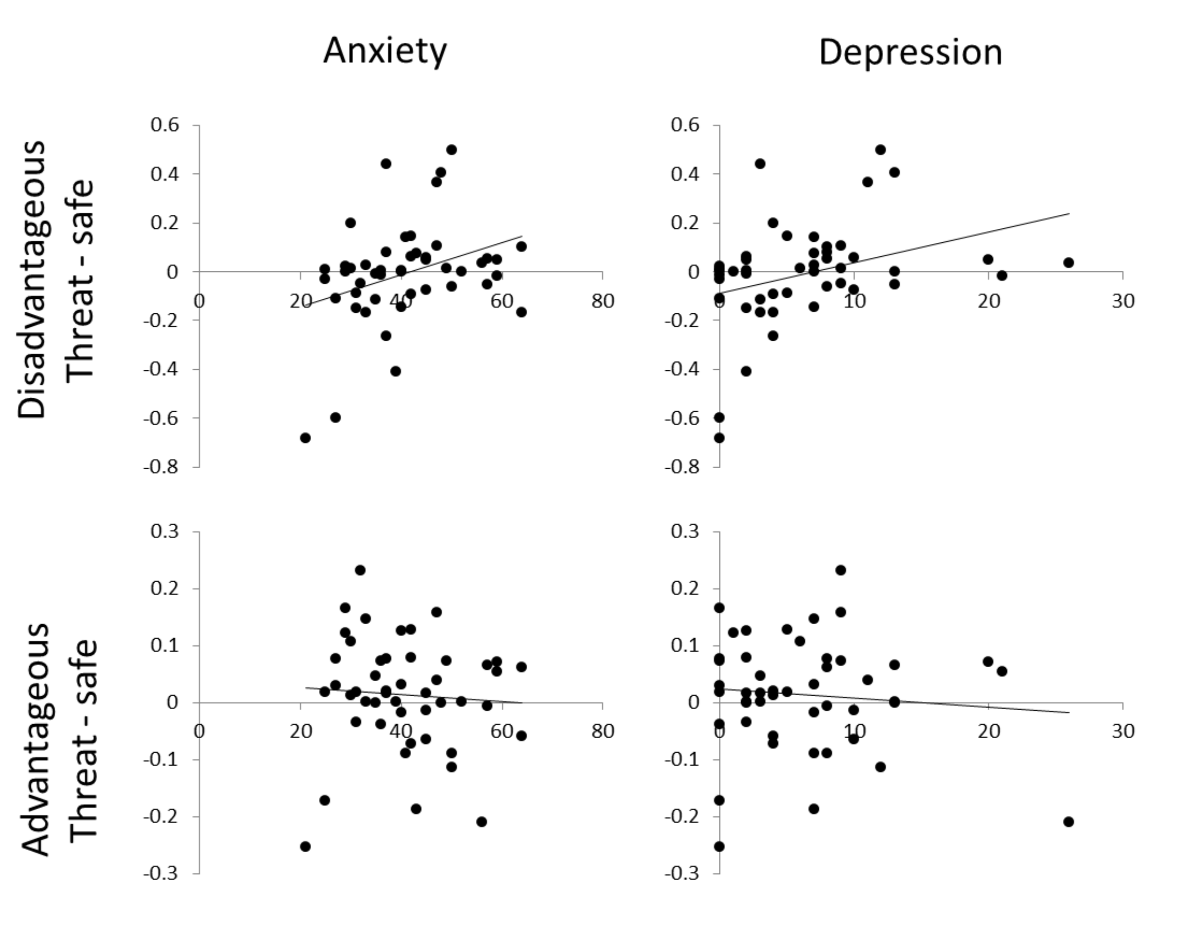
This study also raises a number of questions. First, is this effect on disadvantageous decks simply an epiphenomenon of increased current mood disorder symptomatology, rather than underlying *vulnerability*? From our data we cannot determine the causal relationship between symptoms and stress-induced behavioural change. This question might be addressed through the use of longitudinal designs that follow-up with subjects and determine the relationship between stress-induced behavioural change and subsequent disorder onset. Secondly, why do we see the same effect in trait anxiety and depression scores? Given that they largely account for the same variance (i.e. including both in the same model leads to both interactions becoming non-significant) this may be because both measures tap into the same broad 'negative affect' construct. The significant positive correlation between the measures in this sample provides further support for this as, indeed, does the observation that Depression and anxiety disorders are highly co-morbid (Kessler et al., 2005). Future work should seek to resolve whether depression and anxiety symptoms actually represent separate constructs at a mechanistic level.

Table 1: Behavioural data for good and bad decks in threat and safe conditions across all subjects. RT=reaction time in seconds (standard error of the mean). Choice = proportion of cards chosen from that deck.

	Safe				**Threat**			
	Bad		*Good*		*Bad*		*Good*	
Choice	0.656 (0.032)		0.83 (0.019)		0.649 (0.03)		0.843 (0.019)	
	Play	*Pass*	*Play*	*Pass*	*Play*	*Pass*	*Play*	*Pass*
RT	0.793 (0.039)	0.915 (0.041)	0.779 (0.041)	0.907 (0.052)	0.798 (0.039)	0.902 (0.041)	0.805 (0.044)	0.878 (0.058)

Figure 1: Task schematic. Subjects are given the option to play or pass the deck highlighted in yellow. Outcomes are added or subtracted from the running total displayed at the bottom of the screen. Subjects completed one baseline block whilst safe from shock and one stress block at risk of shock (order counterbalanced).

Figure 2: The effect of stress on participants' propensity to play cards on threat blocks (proportion of cards accepted under threat minus proportion accepted under safe) varies significantly with anxiety and depression symptoms, for disadvantageous but not advantageous decks. N.B. Raw depression scores are depicted but data were transformed with a square-root function for statistical analysis.



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