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Effects of Anticipatory Stress on Decision Making in a Gambling Task

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Recent research has highlighted the fact that emotion that is intrinsic to a task benefits decision making. The authors tested the converse hypothesis, that unrelated emotion disrupts decision making. Participants played the Iowa Gambling Task, during which only experimental participants anticipated giving a public speech (A. Bechara, D. Tranel, & H. Damasio, 2000). Experimental participants who were anticipating the speech learned the contingencies of the choices more slowly, and there was a gender interaction later in the game, with stressed female participants having more explicit knowledge and more advantageous performance and stressed male participants having poorer explicit knowledge and less advantageous performance. Effects of anticipatory stress on decision making are complex and depend on both the nature of the task and the individual.

Keywords: decision making, stress, emotion, gambling, prefrontal cortex

Considerable work has outlined the beneficial effects of intrinsic emotions on decision making, referred to as somatic states (Bechara, Damasio, & Damasio, 2000) or affect heuristics (Finucane, Alhakami, Slovic, & Johnson, 2000). However, in other instances the emotion may be unrelated to the decision-making task; that is, it either existed before the decision-making task or was triggered during the decision-making task through unrelated means. Stress is often incidentally present during decision making, and so this study was designed to test whether incidental, anticipatory stress would be beneficial or disruptive to decision making.

Most of the work on stress and cognition has looked at memory, finding that intrinsic emotion affects memory in an inverted-U-shaped fashion (e.g., Cahill & McGaugh, 1996; Joseph, 1999; Van Londen et al., 1998). In contrast, incidental effects of stress on memory are complex and depend on the task, phase of memory, age and gender of the participants, and even the time of day (al'Absi, Hugdahl, & Lovallo, 2002; Domes, Heinrichs, Reichwald, & Hautzinger, 2002; Het, Ramlow, & Wolf, 2005; Kudielkaa, Buske-Kirschbaumb, Hellhammer, & Kirschbaum, 2004; Parfitt, Hardy, & Pates, 1995; Wolf, Convit, et al., 2001; Wolf, Schommer, Hellhammer, McEwen, & Kirschbaum, 2001).

Most of the work on stress and decision making has been in human factors (e.g., Garvey & Klein, 1993; Klein, 1996), but laboratory research has found that stress impairs decision making when it causes individuals to feel "frazzled" (Arnsten, 1998), such as when participants are stressed by the threat of a shock (Keinan, 1987) or made anxious by a secondary task (Cumming & Harris, 2001). One gambling study found that unrelated stress from exams or negative affect from pictures caused participants to favor less rewarding short-term choices (Gray, 1999).

To study the effects of stress on decision making, we told participants that they would have to give a public speech at the end of the experiment, which has been shown to be a reliable method for inducing stress in the laboratory (e.g., Kudielkaa et al., 2004; Levenson, Sher, Grossman, Newman, & Newlin, 1980; Steele & Josephs, 1988). While anticipating the speech, participants performed the Iowa Gambling Task (IGT), which has been shown repeatedly to rely on an intact somatic marker system, which is affective or emotional in nature. When triggered during the pondering of decisions, these somatic signals help provide internal information about the costs and benefits of alternatives and thus help bias decision making in an advantageous direction (e.g., Bechara, Damasio, & Damasio, 2000; Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Tranel, & Damasio, 2000). Because the stressor was unrelated to the decision task at hand, we hypothesized that the speech anticipation stress would impair performance by creating interference with the task-related emotion necessary to guide advantageous choices. Although a rationale for this hypothesis based on theoretical grounds has been previously

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provided (Bechara & Damasio, 2005), no empirical evidence has been obtained that would support or refute such a hypothesis. This was the primary aim of this study.

Method

Participants

Participants were healthy adults (mean age = 32.38 years, *SD* = 10.69), recruited from and tested at the University of Iowa Hospitals and Clinics. None had neurological or psychiatric illness or were on medication. There were 20 men and 20 women; half of each gender were randomly assigned to the control or experimental group. The experiment was approved by the University of Iowa's Institutional Review Board, and all participants gave informed consent in compliance with federal and institutional guidelines.

Procedures

Briefly, all participants completed baseline questionnaires as well as the original version of the IGT, which served in this study as a practice game. Experimental participants, but not control participants, were told about the public speech. Finally, all participants performed a repeat test version of the IGT, which served as a test game.

The State–Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1977) was used to assess anxiety, and the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) was used to asses changes in positive and negative affect. The STAI–Trait was administered when the participants first arrived; the STAI–State and PANAS were administered when participants first arrived and after the 50th pick in the practice and test games.

After the baseline questionnaires, psychophysiological electrodes were attached inferior to the costal margin and anterior to the sternocleidomastoid muscle to record heart rate using Lead II electrocardiogram in an Astro-Med polygraph (Warwick, RI) at 1000 Hz and simultaneously converted from analog to digital format and transferred to a computer using MP100WS (Biopac Systems, Santa Barbara, CA). The recorded data were analyzed in beats per minute with AcqKnowledge III (Biopac Systems). Heart rate data were collected throughout the practice game, the test game, and the time between the two games, hereafter referred to as the *reveal period*, when the participants were being told about the speech. The effect of the speech manipulation on heart rate response for each participant is referred to hereafter as c, the proportionate change in the reveal period relative to baseline: c = ([mean heart rate for reveal period – mean heart rate for practice game] / mean heart rate for practice game).

The method for administering the IGT was the same as described in prior studies (Bechara, Tranel, & Damasio, 2000) except where noted. Participants were seated at a computer showing four card decks and were instructed to pick one card at a time from any deck and to win as much money as possible. In the IGT, each pick results in both a win and a loss (all monetary changes are hypothetical). Two of the decks yield relatively larger monetary gains (rewards) but also occasional larger monetary losses (punishments), resulting in a net loss if chosen too often. The other two decks had relatively smaller immediate gains (rewards), but the losses (punishments) were also relatively smaller, resulting in a net gain. All participants first performed the original version of the gambling task (the "practice game," also known as Version ABCD, with each letter corresponding to one of the four decks, each with different contingencies). After the practice game, experimental participants were told about the public speaking task awaiting them after the next game (the "test game," also known as the repeat test Version KLMN, with the four new letters referring to the four new contingencies), while control participants sat quietly.

After the practice game and before the test game, only experimental participants were told in detail about the speech to be delivered after the test game. The topic of the speech was "What I dislike about my body and physical appearance," after Levenson et al. (1980). The experimental participants were explicitly told that they would have to speak on the topic for 5 min and that they would be judged on "clarity, organization, articulation, openness, and defensiveness." With the participant watching, a video camera and a microphone were set up and directed toward the participant, a two-way mirror was revealed behind a wooden roll-up screen, and a timer was placed next to the participant's computer screen. The experimenter told the participant that there could be people watching the speech from behind the two-way mirror. The timer was set to 20 min, and the participant was told that the timer would count down to zero during the second gambling task, at which time they would have to give the speech (as a reminder, they were told that 20 min was more than sufficient to finish the task). After the test game and all self-report questions, experimental participants were told that the speech was voluntary and that they would not have to give the speech if they opted not to at that point in the study (cf. Steele & Josephs, 1988). No participants chose to actually give the speech at the end.

Procedures were identical for control participants, except there was no description of a speech before the test game. Participants sat quietly, and the experimenter talked to them briefly to occupy the same amount of time. The camera, microphone, timer, and mirror were hidden from view.

The repeat test version of the IGT (Version KLMN), which was used as the test game in this study, was designed to follow the original IGT (Version ABCD), which was used as the practice game in this study. As such, the contingencies of the four card decks were intentionally made more difficult in order to counteract the effects of practice and learning when individuals play the game in the ABCD version (for more information, see Hernandez & Bechara, 2006; Hernandez, Lu, Hyonggin, & Bechara, 2006). The increased difficulty of the repeat test version, or the test game in this case, introduces variance between the two games, and including both games uses more degrees of freedom, which would decrease the power of the experiment overall. Therefore, in order to increase the statistical power, rather than using a full-factorial, pretest–posttest design we used a between-subjects design on the test game data only. We analyzed gambling performance by subtracting the sum of picks from the two disadvantageous decks from the sum of picks from the two advantageous decks (i.e., [(K + M) – (L + N)]). A separate net score was calculated for each block (20 picks in each of five blocks, totaling 100 picks).

Previous research has revealed that IGT performance improves significantly between the first, second, and third blocks, $t(212) < -2.71$, $p < .01$, when scores reach the asymptote, and that there are no differences between the fourth and fifth blocks, $t(212) > -1.87$, *ns* (Stansfield, Preston, & Bechara, 2003). Thus, to increase the sensitivity of our dependent measures, after an omnibus analysis of variance (ANOVA) comparing across all blocks, we divided the game into the learning phase (Blocks 1, 2, 3—i.e., Trials 1–60) and the performance phase (Blocks 4 and 5—i.e., Trials 61–100) to discriminate anticipatory stress effects on learning the contingencies versus on risk biases after the contingencies have been learned.

To determine the level of explicit knowledge participants had about the four decks, the experimenter interrupted participants after they picked from a disadvantageous deck (and experienced a loss) between Picks 80 and 90 of the test so that participants could mark on a horizontal line how good (to the right) or bad (to the left) they thought each deck was. This is referred to as *explicit knowledge*, measured as the distance in centimeters the mark was to the right for the sum of the advantageous decks minus the sum of the disadvantageous decks ([K + M] – [L + N]). Debates about this technique for assessing explicit knowledge (Maia & McClelland, 2004) are less problematic this late in the game.

Analyses

Analyses were performed using SPSS Version 11.0.4 for Macintosh. Manipulation checks were conducted on *c*, STAI, and PANAS using Student's *t* test to confirm that there were no differences among participants at baseline and to confirm that experimental participants were more stressed. A repeated measures ANOVA was used to compare differences in performance across the five blocks of the test game between control and experimental participants. Because the stressor could affect participants differently in the learning and performance phases of the game, additional analyses were conducted on the learning and performance phases separately in case the manipulation affected those phases differently. Control and experimental participants were compared in the learning phase (Blocks 1, 2, and 3) using an *F* test to look for differences between control and experimental participants in the rate of improvement between the early blocks (3–2 and 2–1); they were again compared in the performance phase (Blocks 4 and 5) using an *F* test to look for differences in average performance in the last two blocks and for explicit knowledge about the decks after the 80th pick.

The alpha level for all comparisons was set at .05.

Results

There were no differences at baseline between the control and experimental participants on state or trait anxiety using the STAI, or positive or negative affect using the PANAS, $F(1, 38) < 1.99$, *ns*; baseline affect data were also not related to any other measures and so are not discussed further. Six participants (1 male control, 3 female controls, 1 male experimental, and 1 female experimental) had missing heart rate data; these participants were excluded from all analyses involving *c*.

Means and standard deviations of heart rate across the whole experiment are provided in Table 1. Experimental participants had greater increases in heart rate from the speech anticipation stress (*c*) than control participants, $t(32) = 3.28$, $p = .003$ (Figure 1); the interaction with gender was not significant, $F(1, 30) = 1.82$, *ns*.

Means and standard deviations of self-report measures across the whole experiment are provided in Table 2. Experimental participants were more anxious during the test game, STAI–State: $t(38) = 2.06$, $p = .047$, and showed a trend toward exhibiting less positive emotion, PANAS–Positive Affect: $t(38) = 1.93$, $p = .061$, than control participants. Both groups had similar levels of negative emotion, PANAS–Negative Affect: $t(38) = -1.13$, *ns*.

Means and standard deviations of gambling performance for each group across the five blocks of the test game are included in Table 3. There was a significant main effect of block, $F(4, 35) = 2.82$, $p = .04$; a post hoc least-squares-differences test found net gambling scores in Block 1 to be significantly lower than in Blocks 2, 3, and 4. There was not a significant difference between the control and experimental participants overall, $F(1, 38) = 0.65$, *ns*, or a Block × Condition interaction, $F(4, 35) = 1.11$, *ns*.

Although there were no omnibus interactions in the test game, there were differences within the learning phase. The speech anticipation stress retarded the learning of experimental participants in the initial blocks (1, 2, and 3). Control participants had the usual steep increase in their performance from Block 1 to Block 2 that leveled off by Block 3, whereas experimental participants failed to improve performance by Block 2, but their delayed learning emerged as they went from Block 2 to Block 3: interaction term, $F(1, 38) = 4.12$, $p = .049$ (Figure 2).

In the performance phase there were no significant differences between control and experimental participants in net gambling scores, $F(1, 38) = 0.07$, *ns*, or explicit knowledge about the decks, $F(1, 38) = 0.46$, *ns*, suggesting that the stressor did not unilaterally affect the performance phase in experimental participants. The speech anticipation stress (*c*) was also not related to these mea-

Table 1
Mean Heart Rate (and Standard Deviation) by Condition Across Blocks and During Reveal

Game	Condition	Block 1	Block 2	Block 3	Block 4	Block 5	Reveal	*c*
Practice	Control	74.52 (11.49)	73.45 (12.13)	73.44 (11.73)	73.11 (11.91)	74.07 (12.31)	75.09 (11.71)	.030 (.045)
	Experimental	74.75 (12.27)	73.12 (12.64)	74.80 (12.89)	74.49 (13.03)	74.53 (12.94)	81.03 (13.99)	.091 (.061)
Test	Control	72.18 (18.39)	71.35 (14.00)	71.74 (13.23)	70.14 (14.11)	72.20 (14.29)		
	Experimental	74.52 (13.59)	75.47 (13.53)	76.24 (13.28)	76.28 (13.71)	76.76 (13.54)		

Note. Values of *c* were calculated from the difference between the reveal period (when subjects heard about the speech) and the baseline average of the practice game.

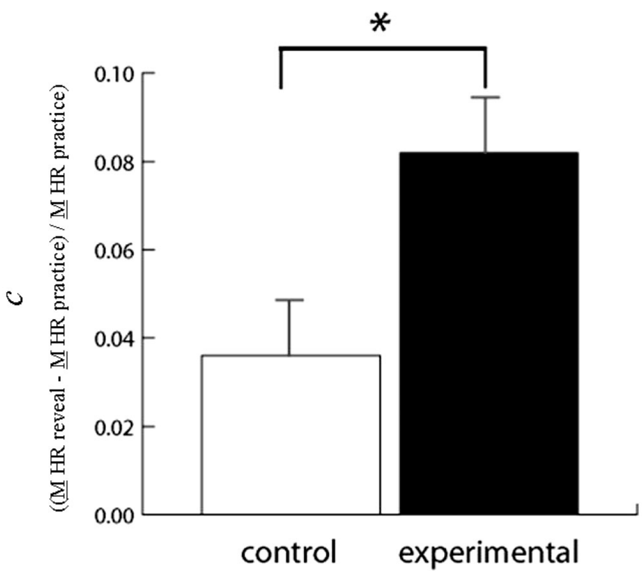

Figure 1. Experimental participants were physiologically aroused by the manipulation. Graph shows percentage change in heart rate for control and experimental participants from the baseline to the reveal period (*c*, calculated as [mean heart rate for reveal period – mean heart rate for practice game] / mean heart rate for practice game) when the experimental participants learned about the speech. Error bars show standard errors. $^{*}p < .01$.

sures in participants overall, or within experimental participants ($r^2 < .031$, *ns*). These null results may be due to differences in the way that male and female experimental participants responded to the manipulation. Experimental female participants tended to have higher responses to the speech anticipation stress than male participants, $t(16) = -1.79$, $p = .09$, but their mean performance phase scores were actually elevated ($M = 4.30$, $SD = 5.31$) as compared with control female participants ($M = 2.60$, $SD = 9.92$); whereas the mean performance phase scores were lower in experimental male participants ($M = 2.00$, $SD = 10.38$) as compared with control male participants ($M = 5.10$, $SD = 8.54$). This interaction was not significant, $F(1, 36) = 0.749$, *ns*, most likely owing to low power in an experiment not designed to test for gender differences, but there was a similar, nonsignificant pattern in the predictions of performance phase scores and explicit knowledge by speech anticipation stress (*c*), with positive *r* values for experimental female participants and negative *r* values for experimental male participants (performance phase: female, $r^2 = .160$, *ns*; male, $r^2 = .165$, *ns*; explicit knowledge: female, $r^2 = .204$, *ns*; male, $r^2 = .259$, *ns*) (Figure 3).

Discussion

The anticipation of giving a public speech was effective as a stressor; it increased anxiety and heart rate only for participants in the anticipatory stress condition and only after the stressor was introduced. Our main finding was that participants in the experimental condition were slower to learn the task, meaning that it took them longer to shift toward advantageous decision making.

Because the main effect was observed in the learning phase and associated with increased arousal and anxiety and decreased positive affect (but not increased negative affect), it is likely that the effect of anticipatory stress on decision making, in the learning phase of this experiment, was mediated by competition between the primary card game and the unrelated speech stressor for limited working memory resources. That is, the experimental participants were initially distracted by thoughts of the pending speech and, thus, either were slower to learn the contingencies of the four card decks or were simply not paying attention to the contingencies until after the second block. Indeed, evidence shows that increased working memory load during the IGT prevents participants from developing the somatic markers associated with the contingencies of the four decks, thus impairing decision making (Hinson, Jameson, & Whitney, 2002), and that this effect is due specifically to a disruption in the executive component of working memory and not to competition for the verbal buffer (Jameson, Hinson, & Whitney, 2004).

Both human and nonhuman studies have found that stress compromises executive functions, and especially working memory (al'Absi et al., 2002; Arnsten, 1998; Arnsten & Goldman-Rakic, 1998; Hartley & Adams, 1974; Hockey, 1970), which in turn impairs cognitive performance, such as mental arithmetic (al'Absi et al., 2002; Veltman & Gaillard, 1993). In addition, because neurochemicals released in response to stress, such as glucocorticoids (Roozendaal, McReynolds, & McGaugh, 2004; Sapolsky, 1992) and dopamine (Adler et al., 2000; Koepp et al., 1998; Pappata et al., 2002), all have receptors in the prefrontal cortex (PFC), it is reasonable to hypothesize that decision-making processes that rely on orbitofrontal portions of the PFC can also be directly affected by stress. Such a system is beneficial for shifting

Table 2
Mean Scores (and Standard Deviations) for Self-Report Scales by Condition and Time Point

Measure	Condition	Baseline	Practice	Test
STAI–Trait	Control	34.9 (6.67)		
	Experimental	38.21 (9.12)		
STAI–State	Control	33.85 (9.84)	36.40 (9.64)	38.75 (9.33)
	Experimental	36.15 (7.68)	38.35 (8.94)	44.90 (9.57)
PANAS–PA	Control	30.80 (6.86)	32.05 (8.94)	30.70 (10.08)
	Experimental	27.15 (7.30)	27.20 (8.45)	24.80 (9.27)
PANAS–NA	Control	12.25 (3.19)	12.80 (2.93)	14.20 (4.76)
	Experimental	13.25 (3.78)	14.45 (5.22)	16.05 (5.58)

Note. STAI = State–Trait Anxiety Inventory; PANAS = Positive and Negative Affect Schedule; PA = Positive Affect; NA = Negative Affect.

Table 3
Mean Scores (and Standard Deviations) for Gambling Performance by Condition and Gender Across Blocks

Condition	Gender	Block 1	Block 2	Block 3	Block 4	Block 5
Control	Male	−3.11 (4.26)	1.78 (4.41)	3.78 (7.38)	6.44 (8.82)	5.33 (9.49)
	Female	1.00 (7.32)	5.20 (8.80)	4.20 (7.39)	3.20 (10.08)	2.00 (11.23)
Experimental	Male	2.80 (9.85)	2.40 (7.82)	5.20 (9.76)	3.40 (12.22)	0.60 (9.52)
	Female	−1.60 (2.27)	0.20 (3.71)	3.40 (6.87)	3.40 (4.53)	5.20 (7.73)

processing under stress away from slower, more deliberative processes that depend on the PFC (Gabrieli, Poldrack, & Desmond, 1998) and toward more automatic, reflexive processes that depend on subcortical areas like the amygdala (Kensinger & Corkin, 2004).

Data indicated that male and female participants might have been differentially affected by the stressor, with female participants performing better under anticipatory stress and male participants performing worse. Given that males normally perform slightly better than females on the task (Bechara, Damasio, Tranel, & Damasio, 1997; Reavis & Overman, 2001) and are more affected by competition and achievement (Ennis, Kelly, & Lambert, 2001; Holt-Lunstad, Clayton, & Uchino, 2001), the effect seems parsimoniously explained by an inverted-U-shaped function of arousal and performance (Yerkes & Dodson, 1908). It is unlikely that any improvement in female performance can be explained simply by a reduced effect of the speech anticipation stress, because the trend was in the opposite direction; that is, experimental female participants were more aroused by the stressor than experimental male participants. One could hypothesize that female participants would be more aroused by a speech having to do with one's body and physical appearance; however, the evidence does not support this hypothesis. The original Levenson et al. (1980) study, using this same speech anticipation stressor, was conducted only with male participants and found significant increases in stress from the speech, with heart rate responses equivalent to those produced by an electrical shock stressor. Moreover, Steele and Josephs (1988) used this same speech anticipation stressor

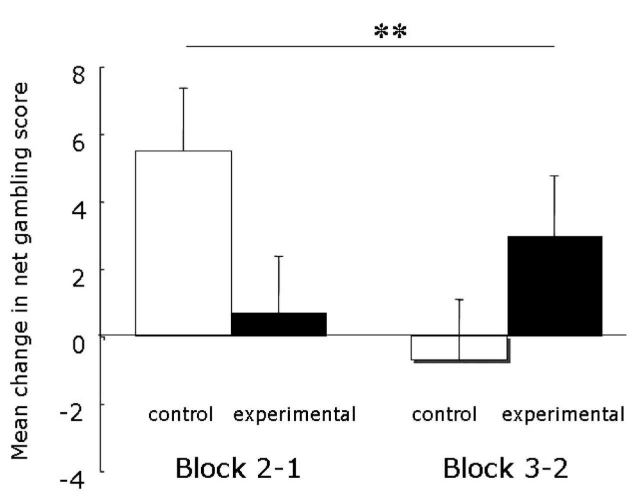

Figure 2. Changes in net gambling score in the learning phase of the test game (during the first three blocks) after the manipulation was introduced in experimental participants. To represent the rate of learning, the previous block is subtracted from the subsequent block (plus or minus one standard error). ** $p < .05$.

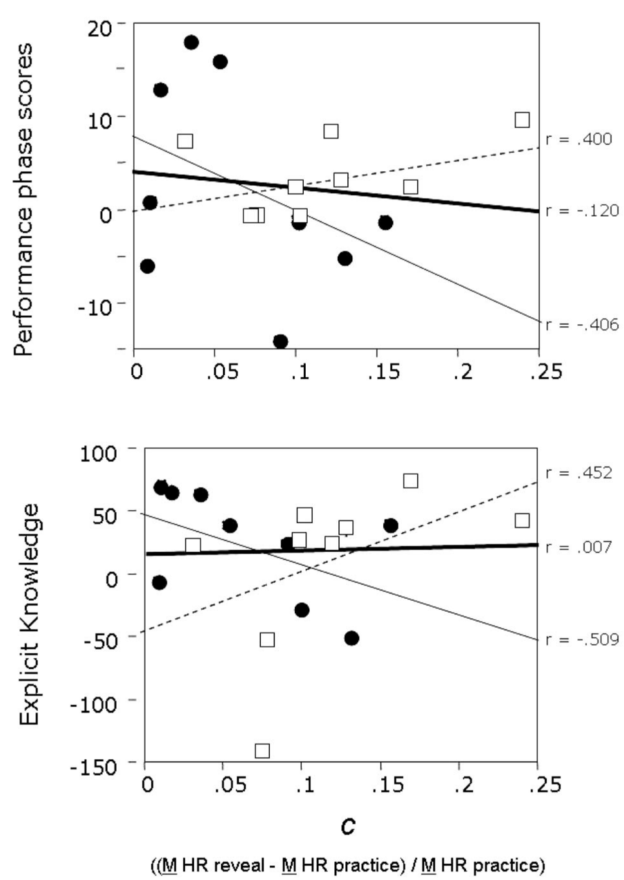

Figure 3. Relationship between speech anticipation stress (c, calculated as [mean heart rate for reveal period – mean heart rate for practice game] / mean heart rate for practice game) on the x-axis and performance phase scores on the y-axis (top graph) and between speech anticipation stress on the x-axis and explicit knowledge about the goodness of the decks (bottom graph). Male participants are represented by filled circles, female participants by open squares. The thick solid line is the regression fit for all experimental participants with complete heart rate data (n = 18); the thin, solid line is the regression fit for males only (n = 9); and the thin, dotted line is the regression fit for females only (n = 9). M HR = mean heart rate.

with male and female participants, and they did not find any effect of gender.

A gender difference in stress and decision making is consistent with a rapidly growing body of literature in brain and behavior research. Using the IGT, Stout and colleagues (Stout, Rock, Campbell, Busemeyer, & Finn, 2005) found that drug-abusing males performed worse on the task than control males, whereas drug-abusing females performed better than control females. Males generally have greater physiological and psychological responses to public speaking tasks than females (Matthews, Gump, & Owens, 2001; Sauro, Jorgensen, & Pedlow, 2003; Steiner, Ryst, Berkowitz, Gschwendt, & Koopman, 2002; Wolf, Schommer, et al., 2001). These gender differences are also mirrored by differential brain responses, with males relying more on the right hemisphere and females relying more on the left hemisphere. This pattern of hemispheric asymmetry has been found in the amygdala in a study of memory for arousing stimuli (Tranel, Damasio, Denburg, & Bechara, 2005) as well as in the PFC in a behavioral study of socioemotional and decision-making performance in ventromedial PFC patients (Bechara, Damasio, & Damasio, 2000) and in an imaging study of the IGT in intact participants (Bolla, Eldreth, Matochik, & Cadet, 2004).

From our research, it seems reasonable to conclude that emotion that is related to the task is advantageous in guiding decisions, providing access to implicit and explicit knowledge about contingencies and likely outcomes. By contrast, emotion that is unrelated to the task may disrupt prefrontal functioning and impair an individual's ability during learning to determine the costs and benefits of their choices. These results are preliminary and based on a small sample; thus, they need to be replicated in a larger sample, one that is especially designed to test for gender differences in the effects of stress on performance. Differential effects of gender in investigations of emotion and performance (memory or decision making) are increasingly common, pointing at psychological differences in the way stressors are appraised and at biological differences in the way stimuli are processed and the way stress hormones affect the brain. Future research can systematically parse the effects of emotion on the learning and performance phases of decision making and compare effects on males and females so that definitive statements can be made about the social and biological effects of emotion on behavioral decisions.

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