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Effects of dilemmas and aromas on performance of the Iowa Gambling Task

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Abstract

Males outscore females on the original version of the Iowa Gambling Task (IGT). This may be due to differential regional prefrontal cortical activation by males and females during the task. PET imagery indicates increased activation in dorsolateral (DL) prefrontal cortex (PFC) in males and in medial orbital (ORB) PFC in females. A recent study reported that females' scores were elevated to the level of males' by having them deliberate moral dilemmas during the IGT. This was presumably due to a relative shift in PFC activation from medial ORB PFC to DL PFC areas. In the present study, after adding new participants and combining results from previous studies we failed to find a significant effect of deliberating dilemmas prior to or during the original IGT performance. However, the typical gender effect was replicated, as was the females' preference for cards from Deck B. The lack of dilemma-enhancement fails to support our previous suggestion of increasing activation in DL during the task. However, we investigated whether activation of ORB (also olfactory cortex) would change IGT performance. When smelling novel aromas during the IGT, males' performance was reduced to the level of females whose performance was unchanged. This finding suggests that activation of emotional neural substrates might alter the dual cognitive (DL)/emotional (ORB) circuits that interact during decision-making.

Keywords

Changes in decision-making; Iowa Gambling Task; dilemmas; aromas; gender differences

INTRODUCTION

During the past 16 years, the Iowa Gambling Task (IGT) has been used in over 100 empirical studies to measure decision-making (Bowman, Evans & Turnbull, 2004). Versions of the IGT have been administered to children (Crone, Bunge, Latenstein, & Heleen, 2005), adolescents (Overman, Frassrand, Ansell, Trawalter, Bies, & Redmond, 2004), young adults in cross-cultural populations (Chiu, Lin, Huang, Lin, Lee, Hsieh, 2008; Reavis & Overman, 2001; Overman, 2004; Overman, Graham, Redman, Eubank, Boettcher, Samplawski, & Walsh, 2006), and elderly adults (Reavis & Overman, 2001). Given the widespread use of this decision-making task, it is important to understand the nuances of task performances such as gender differences and whether performance is subject to alteration by the cognitive and environmental contexts in which the task is given.

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OVERVIEW

This overview will be expanded and fully referenced in the body of the paper: Studies from a number of laboratories have found that normative groups of males out-perform normative groups of females on the original version of the IGT (Bechara, Damasio, Tranel, & Anderson, 1994). This sex difference may be related to differential activation of brain regions between the sexes during their IGT performance. Imaging studies reveal that, among other changes during IGT performance, males show relative increased activation in right DL PFC and females show relative increased activation in medial ORB PFC (BA 11). Using the original IGT version, we have previously reported that females' IGT performance increased to the level of males by having them deliberate moral dilemmas during the task (Overman, et al., 2006). Such deliberation is known, via imaging studies, to activate DL PFC cortex, which is normally activated by males during the IGT. We speculated that contemplating moral dilemmas had partially *shifted females' processing* from medial ORB PFC to more DL PFC. However, this shift hypothesis remains speculative without additional documentation and increased statistical power. In addition, we have consistently found that the gender difference in IGT performance is driven by females' differential preference for cards from disadvantageous Deck B (yellow cards in our studies) coupled with the males' differential preference for cards from advantageous Deck C (green cards in our studies). In the original IGT version, cards in Deck B (yellow) strongly reward (\$100) each choice and strongly punish (-\$1,250) one card choice per 10 choices. In contrast, cards in Deck C (green) weakly reward (\$50) each choice and weakly punish (-\$25 to -\$75) choices on 5 cards per 10 choices.

In the present study, we tested the IGT performance-shift hypothesis in two experiments. In Experiment 1, male and females read, en masse, 20 dilemmas (either personal moral, non-personal moral, or non-moral) immediately *before* performing the IGT. The resulting data were compared with our previous data in which a different dilemma was read between every 10-card choices across 200 IGT trials. There were no statistically significant differences in IGT performance when reading dilemmas *before* as compared to reading them *during* the task. Consequently, subjects from these two sources were combined into the appropriate dilemma groups, doubling our sample size. With the increased number of subjects, a 2 (gender) $\times$ 3 (dilemma) type ANOVA revealed an effect of gender (males outperforming females), but no effect of dilemma type and no gender $\times$ dilemma interaction. Thus, with increased statistical power, the previously reported female enhancement effect was *not corroborated*. However, the gender effect and the female and male card preference effects were replicated.

This finding does not necessarily rule out the possibility that differential cortical activation could influence IGT performance. It is possible that increases in activation of medial orbital systems (activated when females perform the task) might affect IGT performance. Toward this end, Experiment 2 measured IGT performance in males and females when smelling novel or neutral odors between every 10 IGT trials. The logic behind this study was as follows: (1) there is increased activation in medial orbital PFC cortex (which is secondary olfactory cortex) in females during IGT performance (Bolla et al., 2004), and (2) in our studies, and in the imaging study, females do not perform as well as males. Thus, we predicted that olfactory stimulation during IGT might alter activation in medial orbital PFC in males and females and consequently, males might perform similarly females (poorer than normal). Indeed, when males smelled novel odors, their IGT performance *decreased* to the level of females. When males smelled neutral odors, their performance did not change from normal baseline and remained significantly higher than females'. Females' IGT performance did not change under either odor condition.

BACKGROUND

IOWA GAMBLING TASK (IGT)

The IGT (Bechara, et al., 1994) requires that participant choose cards from among four decks. In this version of the task, cards in two of the decks (advantageous) are associated with low monetary rewards (\$50), but even lower sporadic losses. Cards in the other two decks (disadvantageous) are associated with high rewards (\$100), but even higher sporadic losses. Consistent choice of advantageous cards results in long-term gain (+\$250 per 10 trials), whereas consistent choice of disadvantageous cards results in long-term loss (-\$250 per 10 trials). Over the course of 100 to 200 trials, normative control subjects formulate the strategy of picking from the low-paying advantageous decks, resulting in long-term gain.

NOTE: In most IGT studies, the two advantageous decks are labeled C and D and the two disadvantageous decks are labeled A and B. In our laboratory these decks have been designated by colors. This is because, shortly after the original IGT was reported, we created computerized version with color-labeled decks. Comparisons of IGT studies using letter designations with our color designations show that this factor makes no difference in performance for males or females. Males outscore females when decks are lettered (Bolla, et al., 2004) or colored (Overman, et al., 2006).

Optimal performance on the IGT is dependent on the integrity of several regions of the prefrontal cortex including the orbital PFC (ORB PFC) (Bechara, Damasio, Damasio, & Anderson, 1994; Fellows & Farah, 2005), the dorsolateral (DL PFC) (Fellows & Farah, 2005; Manes, et al., 2002), and the dorsomedial PFC (DM PFC) (Manes et al., 2002). Damage to any one of these areas produces impairments on the IGT as defined by selection of more disadvantageous cards. Additionally, there is a laterality effect in that the right hemisphere is more important than the left hemisphere in decision-making, with regard to the roles of the DL PFC (Clark, Manes, Antoun, Sahakain, & Robins, 2003) and the ORB PFC (Manes et al., 2002; Tranel, Bechara, Denenberg, 2002).

In addition to brain-damaged patients, several patient populations perform poorly on the IGT relative to normative populations. A non-exhaustive list includes polysubstance abusers, cocaine abusers, alcohol abusers, heroin addicts, violent offenders, suicide attempters, pathological gamblers, obsessive-compulsive patients, adolescent binge drinkers, and anorexic patients (see Overman et al., 2004, 2006 for referenced lists). Normative adolescents also perform poorly on the IGT, but not as poorly as the patients mentioned above (Overman, et al., 2004).

Gender differences in IGT performance—One consistent finding (unfortunately not analyzed in many IGT studies) is that males choose more \$50 advantageous cards than do females on the IGT (Bolla et al., 2004; Overman, 2004; Overman, et al., 2004; Reavis & Overman, 2001), and on similar gambling tasks (Stout, Rock, Meghan, Campbell, Busemeyer, & Finn, 2005; Yechiam, Stout, Busemeyer, Rock, and Finn, 2005). All studies from our lab have documented this sex difference in participants ranging in age from 12 to 60 years of age. While both males and females learn to select more advantageous cards than disadvantageous cards across the IGT trials, females, as a group, consistently choose a higher number of disadvantageous \$100 deck B (yellow) cards. Deck B is distinctive in that every card choice is rewarded by \$100 while, on average, one card per ten is punished by -\$1250. Thus, Deck B has a high reward to high punishment ratio of 9:1. While it is not entirely clear why females select significantly more \$100 B (yellow) disadvantageous cards than do males, two possibilities have been ruled out: differential patterns of response perseveration by males and females and differential math ability of males and females (Overman et al., 2006). Numerous other studies have reported similar choice patterns on the

IGT. These studies reveal that subjects display a dual selection process during the IGT: (1) selection of advantageous cards from Decks C (green cards) and D (red cards) as well as (2) selection of cards that have a high pay-off frequency, i.e. cards from disadvantageous Deck B (yellow cards) and sometimes from advantageous Deck D (red cards) (see Lin et al., 2007 & Stocco et al., 2009, for reviews). Unfortunately, many of the studies outside our lab failed to conduct a gender analysis, used a low number of subjects, and employed only 100 IGT trials. These shortcomings render a direct comparison with our data (that include a gender analysis and 200 IGT trials) unfeasible.

Possible neural explanation for gender differences on the IGT—It is possible that the sex difference in IGT performance is related to differences in cortical activation in neural regions during the task. A PET study by Bolla et al., (2004) analyzed increases in brain activation in males and females while they performed the IGT. Males showed significant activation in two clusters: a large cluster in right lateral orbital frontal cortex (OFC)(BA 47) and a smaller one in left lateral OFC (BA 11). In contrast, females showed one significant cluster of increased activation in left medial OFC (BA 11). When the entire brain was screened for activation, males showed large areas of increased activation in right lateral OFC (BA 47), DL PFC (right BA 10; right BA 9), and the right parietal lobe (BA 40). According to a laterality index, males demonstrated extreme right hemispheric lateralization while females did not demonstrate lateralization. A between-gender analysis revealed that, during the IGT, males showed significantly greater activation than females in right BA 47 and BA10 while women showed greater activation than males in left BA 9.

The lateral OFC is sensitive to punishment and overrides prepotent behavior based on previously rewarded stimuli, whereas the medial OFC is involved in reward and guessing situations when the outcomes are uncertain (Elliot, Dolan, Frith, 2000; O'Doherty et al., 2001). Bolla et al., (2004) suggests that this may explain why females select a higher percentage of \$100 Deck B (yellow) disadvantage cards (with 9:1 large rewards). In contrast, the lateral portions of OFC, the portion that increases in activation in males during the IGT, are correlated with the penalties related to a decision (Elliot et al., 2000). This may explain why men do not select the disadvantageous \$100 Deck B (yellow) cards as often as females, i.e. males may learn to avoid the high penalties associated with this card. Bolla, et al., (2000) suggest that because of the regional differences in neural activity, men and women perceive the valences of the IGT differently. Another fundamental difference is that males, but not females, show increases in activation of right DL PFC during the IGT (Bolla et al., 2004), an area known to mediate a number of cognitive functions such as working memory.

Deliberation of dilemmas also increase activation in PFC—Studies by Greene and colleagues (Greene et al., 2001; Greene & Haidt, 2002; Greene, Nystrom, Engell, Darley & Cohen, 2004) have used fMRI to measure neural activity during contemplation of Personal Moral, Non-Personal Moral, and Non-Moral Dilemmas. Each of these is defined in the procedure section below. Greene et al., (2001) utilized 20 dilemmas of each type. fMRI data revealed that, as compared to NPM dilemmas, during contemplation of PM dilemmas, significantly more activity was seen in the medial portions of BA 9,10, BA 31 and BA 39. In contrast, deliberation of NPM dilemmas increased activation in DL PFC (BA 46). Areas associated with less activation during contemplation of PM dilemmas, as compared to NPM and NM dilemmas, were BA 39 (bilateral), BA 46, and BA 7/40 (bilateral). More recently, Greene et al., (2004) reported that deliberation of difficult PM dilemmas (defined as those dilemmas with a long response time) increased activation in DL PFC 10 and 46 as well as anterior cingulate (BA 32) and inferior parietal lobe (BA 40 & 39). Almost the same area (Talairach coordinates 28, 49, 6) showed increased activation when the difficult PM dilemmas were answered with utilitarian responses (answers that serve the common good).

It is important to note that both of these lateral dorsal regions are extremely close to the right DL PFC regions (Talairach coordinates 30, 47, 1) activated in males during performance of the IGT (Bolla et al., 2004).

These background data led to a prediction and recently published study—

Summary of background data: (a) lesion studies indicate that both DL PFC and ORB PFC regions play critical roles in decision-making; (b) males out-perform females on the IGT; (c) superior male performance is correlated with increased activation in right PFC areas BA 9, 10 and 47 (bilateral); (d) certain types of cognition (dilemma deliberation) increases activation in PFC areas including the same lateral DL PFC areas activated in males during the IGT.

These findings led us to the prediction that deliberation of PM and / or NPM dilemmas might enhance females' IGT performance by putatively shifting activation to "male" decision-making regions as defined by Bolla et al., (2004) and that this activation would lead to a reduction in female preference for the \$100 Deck B (yellow) disadvantageous cards. Overman et al., (2006) tested this prediction by having 200 participants perform the IGT when they silently read a PM dilemma, or NPM dilemma, or NM dilemma every 10 trials. Each participant read only one type of dilemma during the course of 200 IGT trials. The dilemmas were those used by Greene et al., (2001, 2004). Deliberations were not timed and at the end of the each deliberation, the subject marked an answer sheet as "appropriate" or "inappropriate".

The results showed that when reading PM dilemmas, females' IGT scores appeared to be elevated to the level of males' as there was a not a significant difference between male and female scores in this condition. Males outscored females in the NM and NPM dilemma conditions as typically found (Overman et al., 2006). Females chose significantly fewer \$100 Deck B (yellow) disadvantageous cards in the PM condition than in the NM and NPM conditions. Males, however, did not differ in their choice of Deck B (yellow) cards in any dilemma condition. Also, the performance of both males and females steadily improved throughout the task as they picked increasingly more advantageous cards.

Based on these results, we speculated (Overman et al., 2006) that females' deliberation of PM dilemmas, or perhaps a subset of PM dilemmas (the difficult ones as defined by Greene et al., 2004) improved IGT performance because it shifted relative activation to the DL PFC, the area males typically used during the task (Bolla et al, 2004). We suggested that both the deliberation of PM dilemmas and execution of the IGT require the use of cognitive faculties that are mediated by similar neural systems. Both tasks require the recall of past conflicts, resolutions, and outcomes. Both require the contemplation of the consequences of behavioral choice. Perhaps the deliberation of PM dilemmas enables and / or primes participants to more carefully consider the consequences of selecting various card types.

PRESENT STUDY

EXPERIMENT 1: Deliberating dilemmas before IGT performance

While it was interesting that PM dilemmas contemplated *during* the IGT appeared to enhance females' performance, it would be much more significant if reading the dilemmas *before* IGT performance had an enhancing effect. As a first step in exploring this possibility, in Experiment 1, three groups of college-age participants read, en mass, 20 personal moral (PM), or 20 impersonal moral (IM), or 20 non-moral (NM) dilemmas prior to performing 200 IGT trials.

METHOD

Participants

One hundred and eighty college students (88 males and 92 females) served in this study as per course requirements. Participants were randomly assigned to one of three groups; Personal Moral dilemmas (PM: 30 males and 30 females), Non-Personal Moral dilemmas (NPM: 28 males and 32 females) and Non-Moral dilemmas (NM: 30 males and 30 females).

Materials and Procedures

The dilemmas were those used by Greene et al., (2001, 2004) and Overman et al., (2006). The IGT was the same as in previous experiments (Overman, et al., 2004). Personal Moral Dilemma (PM): According to Greene et al., (2004), a Personal Moral Dilemma must meet three criteria: first, a violation must be likely to cause bodily harm. Secondly, the harm must befall a person or persons. Third, the harm must not result from the deflection of an existing threat onto a different party. An example is: “There is a trolley heading down a track. If it veers right it will kill five workmen. On an overhead bridge is a very large man. The only way to save the five people is for you to push the large man in front of the trolley to stop it. Is it appropriate for you to push the man?”

Non-Personal Moral Dilemma (NPM): is defined as a dilemma that does not meet one of the three criteria above (Greene, et al., 2004). An example is: “There is a trolley heading down a track. If it veers right it will kill one workman but if it veers left it will kill five workmen. Is it appropriate for you to throw a switch so that the trolley veers right, killing the one workman but not the five?”

Non-Moral Dilemma (NM): is defined as meeting none of the three criteria and not involving “moral” judgment. An example is: “You are a farmer driving a turnip harvester. You are approaching diverging paths. If you drive down the right path you will harvest 10 bushels of turnips and if you drive down the left path you will harvest 20 bushels. If you do nothing the machine will turn to the left. Is it appropriate for you to turn right in order to harvest 20 bushels?”

The subjects were told that they would read 20 passages, mark each one as appropriate or not appropriate, and then play a card game. After silently reading the 20 dilemmas, at their own rate, the participants were given standardized instructions about the IGT as reported in Overman, et al., (2006) and participated in the card task

As has been the case in our lab, the IGT was presented on a computer screen that showed the net gains and losses of cards selected from each deck. As is the practice in our laboratory, subjects chose real cards from four decks. Subjects’ selections were duplicated by the researcher who clicked the corresponding card on the computer screen. The decks consisted of two advantageous \$50 Decks C and D (green and red) and two disadvantageous \$100 A and B decks (blue and yellow). The spatial positions of the decks, presented in quadrants, were randomized on the desk and computer screen for each subject. As was the case for all experiments in this paper, procedures were approved by the university IRB.

RESULTS

The 2 (gender) $\times$ 3 (condition) ANOVA revealed no significant effect of gender, $F(1, 174) = .192$, $p = .66$, no significant effect dilemma conditions, $F(1, 174) = 1.98$, $p = 0.141$, and no significant interaction between gender and dilemma condition, $F(2, 174) = 0.596$, $p = 0.552$. These data are shown in Figure 1. As shown by the error bars, there was variability in scores. In terms of absolute measures, males out scored females in both the PM and NM

condition but the large variances prevented these differences from being statistically significant.

As typically seen in normative subjects, both males and females demonstrated learning across the 200 IGT trials. The 200 trials were divided into 4 blocks of 50 trials and the percentage of \$50 Deck C + D (green + red) advantageous cards was entered into a 3 (dilemma conditions) $\times$ four (4 blocks of 50 trials) ANOVA. There was a significant block effect for both males and females, $F(3, 264) = 44.61, p < 0.0001$ and $F(3, 267) = 28.52, p < 0.0001$, respectively. There were no significant effect of dilemma type nor gender $\times$ dilemma interactions for either males or females, all p 's > 0.05 .

Experiment 1 Further Analysis: Comparison with previous data when dilemmas were read during the IGT

At this point, the IGT data from all of our research were not in total agreement. Previously, the data appeared to reflect an IGT enhancement effect when females read single PM dilemmas every 10 trials (Overman, et al, 2006). But this enhancement effect was not evident when dilemmas were read *prior* to IGT performance. In both studies, the number of subjects was somewhat limited and the performance variances were substantial. Thus, we directly compared results from the two studies. A 2 (gender) $\times$ 2 (experiment condition, i.e., reading *before* and *prior* to IGT) $\times$ 3 (dilemma type) ANOVA was conducted. The results showed a significant effect of gender, $F(1, 365) = 5.39, p = 0.021$ in which males outscored females in picking advantageous Deck C + D cards (green + red cards) (males = 68.7%, females = 65.17%). However, there was no significant effect of experimental condition (reading before or during the task), $F(1, 365) = 2.27, p = 0.132$ and no significant effect of dilemma type, $F(2, 365) = 2.44, p = 0.089$. None of the interactions were statistically significant p 's > 0.05 .

A 2 (gender) $\times$ 2 (experimental condition, i.e., dilemmas before or during IGT) $\times$ 3 (dilemma type) ANOVA was run for each card type. The results showed a significant gender effect only for two decks: disadvantageous Deck B (yellow cards) and advantageous Deck C (green cards), ($F(1, 365) = 7.89, p = 0.005$ and $F(1, 365) = 3.82, p = 0.051$, respectively). When picking from Deck B (yellow cards) females chose significantly more cards (21.65%) than males (18.49%). When picking from Deck C (green cards) males chose significantly more cards (33.40%) than females (30.50%). The only other significant finding was that more Deck B (yellow cards) were chosen when dilemmas were read *during* the IGT (21.17%) than when read *prior* to IGT (18.96%), $F(1, 365) = 3.87, p = 0.05$. There were no significant effects of gender, testing condition or interactions for any other deck type. There was no significant main effect of dilemma type for any deck, p 's > 0.05 .

In summary, when the two dilemma reading conditions (reading prior to vs. reading during the IGT) were compared, there was a significant gender effect in which males outscored females in picking advantageous cards from Deck C + D (green + red cards). This gender difference was driven by females' choosing significantly more cards from disadvantageous Deck B (yellow) and the males choosing significantly more cards from advantageous Deck C (green) cards. Both results have been consistent findings in our laboratory (Overman et al., 2004, 2006).

At the present time, when considering and comparing multiple data sets, it appears that there is not consistent evidence that reading any type of dilemma before or during the IGT substantially changes performance for males or females. However, the gender effects documented in our previous studies (Overman et al., 2004, 2006) were confirmed in the present analysis: (1) the higher male performance for choosing from the advantageous decks

C + D (green+ red cards) (2) the female preference for cards in Deck B (yellow cards) and (3) the male preference for cards in Deck C (green cards).

Increasing Power—To more thoroughly investigate these effects we increased statistical power by combining the performance of subjects who read dilemmas *prior* to with those who read dilemmas *during* the IGT in to one “IGT-Dilemma” group of 377 subjects. (This combination was justified because in the previous analysis, performance of the two groups did not differ.) This combined performance was compared with all subjects who performed only the IGT (i.e., without additional cognitive tasks). In other words, IGT performance was compared between an IGT-Dilemma Group and an IGT-Only Group

The IGT-Only group consisted of 227 subjects. This group was a composite of two subgroups. One subgroup consisted of equally performing age groups in an earlier study (Overman, et al., 2004) [11th grade: 26 males and 25 females; 12th grade 30 males and 27 females, college students: 30 males and 29 females]. The other subgroup consisted of never-before-reported college students who performed the IGT: 30 males and 30 females. There were no performance differences in these two subgroups. Consequently the resulting IGT-Only group consisted of 116 males and 111 females.

A 2(gender) $\times$ 2 (IGT condition, i.e. OGT-Dilemma or IGT- Only) ANOVA for selection of advantageous Decks C + D (green + red cards) revealed a significant effect of gender, $F(1, 600) = 13.36$, $p=0.000$, no IGT condition effect (dilemma vs. IGT only), $F(1, 600)= 0.029$, $p= 0.865$; no significant interaction, $F(1, 600) = 0.329$, $p=0.56$. Males outscored females in selection of advantageous Decks C + D (green + red cards) (69.2% vs. 64.8%), (Figure 2).

Previous studies have shown that participants often allocate their choices on the IGT based upon two distinctly different strategies (Lin, et al., 2007; Overman et al, 2004, 2006; Scocco et al., 2009). Some subjects select cards that pay off in the long run, i.e. advantageous cards from decks C and D (green and red). In contrast, other subjects appear to select cards according to their *reward frequency*, i.e. decks B and D (yellow and red cards). These two decks have a 9:1 ratio of reward to punishment for each 10 consecutive selections. Decks A and C (blue and green cards) have a 5:5 ratio of reward to punishment for each 10 consecutive selections.

In order to assess whether males and females were significantly different in their selection of cards based upon *frequency* of reward, choices from the yellow + red decks (B + D cards) were combined as the dependent variable. A 2 (gender) $\times$ 2 (IGT condition, i.e., dilemma IGT or dilemma-only IGT). The analysis revealed a significant effect for gender, $F(1, 600) = 5.65$, $p = .018$. with females (58.06%) selecting more B+D cards than males (55.34%). No significant effects were found for the main effect of IGT condition, $F(1, 600) = 1.68$, $p = .195$ or for the interaction, $F(1, 600) = .086$, $p = .769$. As expected, when the low-ratio blue and green decks (A + C cards) were combined, the 2 (gender) $\times$ 2 (IGT condition, i.e., dilemma IGT or no-dilemma IGT) ANOVA revealed a significant effect for gender, $F(1, 600) = 5.56$, $p = .019$ with males (44.29%) selecting more A+C cards than females (41.66%). No significant effects were found for the main effect of IGT condition, $F(1, 600) = .799$, $p = .372$ or for the interaction, $F(1, 600) = .115$, $p = .735$.

A subsequent analysis showed that the gender differences reported above was driven by females strong preference for cards in disadvantageous deck B (yellow cards) and males' preference for cards in advantageous deck C (green cards). This finding was revealed via a series of 2 (gender) $\times$ 2 (IGT condition, i.e., dilemma IGT or no-dilemma IGT) ANOVAs for *each* type of deck. This analysis once again showed significant effects for gender for the Deck B (yellow) and Deck C (green) cards, $F(1, 600) = 20.55$, $p=0.000$, and $F(1, 600) =$

6.331, $p = 0.012$, respectively. Females chose more cards for, disadvantageous Deck B (yellow) (22.19%) than did males (18.15%). Males chose more advantageous cards from Deck C (green cards) (32.23 %) than did females (29.27)

Summary and Discussion of Experiment 1—Following a number of different analyses of current and previous data, and despite increased statistical power, we fail to find a consistent effect of reading moral dilemmas prior to or during performance of the IGT. This is in contrast to what we have reported previously (Overman, et al., 2006). However, all of the data sets and analyses indicate that males choose more advantageous cards than do females. This gender differences appears to be driven by females' higher preference for cards from disadvantageous Deck B (yellow). This, in turn, renders a higher choice by men from advantageous deck C (green cards) since females and males are equal in choosing from the other two decks.

It is important to note, that both males and females learned the task contingencies as evidenced by increasing choice of advantageous cards across blocks of trials. Females, however, were also influenced by the motivational impetus provided by cards from Deck B (yellow) that offered one large punishment among ten large rewards every 10 trials.

These data agree, in general, with several recent conceptual frameworks according to which behavior on the IGT reflects two dissociable processes: one that tracks each option's long term outcome and one that is sensitive to frequency and magnitude of rewards and punishers (Chiu et al., 2008; Brand, Labudda, & Markowitsch, 2006; Scocco et al., 2009;). Our gender analysis further refines this dual-process hypothesis and suggests that the long-term-gain process occurs more often in males and that the frequency-of-reward process occurs more often in females. The present data agree with those of Stout et. al., (2005) that suggest females, unlike men, fail to show attentional disparity to wins versus losses.

One plausible psychological/neurological explanation for these results has been espoused by Bolla et al., (2004). These researchers suggest that males and females perceive the valences of the IGT task differently. The underlying mechanism for this difference is that males and females show increases in activity in somewhat different regions of PFC during IGT performance. More specifically, due to activation of lateral OFC, males are more sensitive to punishment and avoid cards with large penalties whereas, due to activation of medial OFC, females are more sensitive to large, frequent rewards, and select decks such as deck B (yellow cards).

EXPERIMENT 2

Olfaction and IGT Performance

If increases in activation of medial orbital PFC are related to females' selection of high frequency, high-reward cards as suggested by Bolla et al., (2004), then perhaps stimulation of this area in males, might render their performance like those of females, and result in a male increase in selection of deck B (yellow cards).

In this experiment, we *putatively* stimulated ORB PFC by having participants smell and rate aromas during the IGT. We predicted that this would activate secondary olfactory cortex, BA 11, the area females normally show increased activation in during the IGT (Bolla et al., 2004). Furthermore, we predicted that this would result in a *decline* in IGT performance *for males*, but yield no change in females' performance.

The logic is as follows: ORB PFC receives input from many sensory systems including olfactory, gustatory, visceral, somatic sensory and visual (for review see Ongur & Price,

2000; Price, 2006; Rolls, 2004). This constellation of inputs, along with intimate limbic relationships, provides integration of sensory information, especially for the taste and olfactory assessment of food choices, and for other emotionally-related decisional behaviors (for review see Zald and Rauch, 2006). ORB PFC is immediately rostral to primary olfactory cortex, which in turn, receives direct inputs from the olfactory bulb (Price, 1990). Primary olfactory cortex consists of piriform cortex, entorhinal cortex, periamygdaloid cortex, olfactory tubercle, the tenia tecta and anterior nucleus (Carmichael, Clugnet and Price, 1994). Of particular importance is the fact that the largest recipient of bulbar input, the piriform cortex, has direct connections with the ORB PFC. Specifically, piriform cortex projects to posterior ORB PFC (BA 13a, 13m) (Price, 2006) which in turn, projects to other orbital areas including BA 11 L (Price, 2006). [There is a smaller olfactory input to ORB PFC via the mediodorsal nucleus of the thalamus (Price, 2006).]

In summary, anatomical and physiological data indicates that olfactory bulbar information is projected via only two or three synapses to posterior OFC (including areas BA 13 and 11). There are three critical links between these facts and the present study. First, patients with damage to OFC perform abnormally in real-life decision-making and on the Iowa Gambling Task (Bechara et al., 1996, 1997). Secondly, patients with damage to OFC are impaired in olfactory discriminations (Jones-Gotman & Zatore, 1993). Third, the PET study by Bolla, et al., (2004), ORB PFC (BA 11) showed increased activity in females during performance of the IGT. The converging anatomical and behavioral evidence that ORB PFC receives olfactory information suggested to us that this area could be activated by presentation of aromas.

Hypothesized effects of smelling and rating aromas on IGT performance—

Since, when performing the IGT, females show increases in activity in olfactory PFC (BA 11) and males show increases in activity in other areas (BA 47, 9 & 10) (Bolla et al., 2004), we speculated that smelling/rating aromas [and putatively increasing activation in medial ORB PFC (BA 11)] might alter the balance between the dorsolateral and orbital circuitry shown to be active during IGT performance (Bolla et al., 2004) in favor of ORB PFC and thus, lower males' IGT scores to the level of females' scores. In this experiment, we required participants to intermittently smell and rate novel odorants during performance the IGT.

METHOD

Participants

A total of 278 subjects (139 males and 139 females) participated in this study. All were college students (ages 17-23) enrolled in introductory psychology courses. They participated for a research requirement in the course. The UNCW IRB approved all aspects of the study.

The participants were randomly divided into two groups: an experimental group (n = 139, 70 males, 69 females) and a control group (n = 139, 69 males, 70 females). Participants in the experimental group smelled and rated a different novel aroma every 10 trials during performance of the IGT. Two ml of each aroma were mixed with sterile sand in a small glass vial. Control group participants smelled and rated a neutral aroma (vials containing only sterile sand) every 10 trials during performance of the IGT.

Materials

Each participant completed the task individually in a small room with the experimenter, a computer and a desk. To insure adequate olfactory ability, prior to the IGT participants completed the short version of the Pennsylvania Smell Test (Doty, Shaman & Dann, 1984),

the Pocket Smell Test™ (PST) (Sensonics, Inc.). This test consists of “scratch and sniff” odorants embedded in microencapsules that are positioned in three strips at the bottom of a single booklet page. The odorant stimuli are released by scratching the strips with a pencil point. Above each odor strip is a multiple-choice question with four alternative responses, for example: “This odor smells most like: a) chocolate; b) banana c) onion; d) fruit punch”. The criteria for selection of odorants and response alternatives have been thoroughly described previously, and the test-retest reliability of the PSTTM exceeds 0.90 (Doty, Shaman, & Dann, 1984). In order to be included in the present experiment, subjects had to correctly identify three out of three odorants. Thirty-three subjects did not meet this criterion. They were tested, but excluded from data analysis and inclusion in this report. It is important to note that the PSTTM is a test of olfactory *ability* rather than a method to engage the olfactory system for any length of time.

The materials for the IGT were exactly as previously reported (Overman et al., 2006). Aroma stimuli consisted of two ml of an essential oil mixed with and absorbed in 15 ml of sterile sand, which was contained in small glass vials (see Appendix I for a list of the oils).

Each vial was wrapped with masking tape, numbered, and topped with a screw cap. Control group participants smelled only sterile sand in a vial in otherwise identical conditions as the experimental group. For every “odor” in the control condition, a new vial was opened for the participant who was asked to sniff and rate the “odor”. It is important to note that the control vials did, in fact, have a very slight odor, i.e. from the sand and perhaps some odor from the plastic cap. However, this odor was extremely faint, consistent from trial to trial, and was present in the experimental group as well.

Procedure

Due to reports of laterality effects in olfaction judgment (Royet et al., 2001; Royet & Plailly, 2004), odors in the present study were presented to only one nostril, right or left. This was accomplished by placing a piece of 3M Microfoam™ surgical tape over one nostril before starting the IGT. By placing tape over one nostril and pressing it around the nostril, it is possible to block the nostril without distorting the septum or disrupting the function of the open nostril. This technique has been the standard technique for unilateral olfactory delivery in previous studies (Bromley & Doty, 1995; Doty, Stern, Pfeiffer, Gollomp, & Hurtig, 1992).

Before beginning the IGT, subjects were read the standard instructions (Overman, et al., 2004). The procedures for IGT were identical to those in Experiment 1. The experimental session began by having the subject hold a vial under the open nostril and sniff the aroma for three seconds. The vial was then closed and the participant rated the aroma on two 5-point rating scales (a pleasantness scale and an intensity scale) with the score of 1 being least pleasant or intense and the score of 5 being the most pleasant or intense. There were no requirements for identification or other verbal description of the aroma. Next, the subject completed 10 trials of the IGT. After every 10 trials, the subject was asked which two decks were the “good” decks. Then, a second aroma was presented and followed by 10 trials of the IGT and so on for 200 IGT trials and 20 aromas. Each subject smelled the 20 odors in the same numerical order.

RESULTS

Aroma ratings

There were no significant differences for nostril delivery in males or females in rating aromas for pleasantness or intensity, p 's $> .05$. Data from right and left nostril were collapsed. In this combined group there were no significant differences between males and

females in rating intensity of aroma (male $M = 3.19$, female $M = 3.20$) or pleasantness of aroma (male $M = 2.52$, female $M = 2.36$), p 's > 0.05 . In addition, there were no significant correlations in either males or females between aroma intensity or aroma pleasantness and performance on the IGT, all p 's > 0.05 . In other words, the odorants were rated, on average, as moderately intense and slightly below midline of neutral in pleasantness. No single aroma or combinations of aromas were differentially preferred by males or females.

IGT Performance

Performance on the IGT was measured as percentage of advantageous \$50 Deck C + D (red + green) cards across 200 trials. A 2 (nostril) $\times$ 4 (blocks of trials) ANOVA again indicated that no difference in IGT performance as a function of nostril delivery for either experimental aroma male group, $F(1, 68) = 0.88$, $p = 0.349$ or for the experimental aroma female group, $F(1, 67) = 1.82$, $p = 0.181$. Similarly, no difference in IGT performance were found as a function of nostril delivery for the neutral aroma male control group, $F(1, 67) = 0.69$, $p = 0.793$ or for the neutral aroma female control group, $F(1, 68) = 0.997$, $p = 0.322$.

Consequently, data from the right and left nostrils were collapsed into four groups: Male Experimental (aroma, $n = 70$ males), Female Experimental (aroma, $n = 69$), Male Control (neutral aroma, $n = 69$), and Female Control (neutral aroma, $n = 70$). Each of the four groups showed significant learning across the task, in terms of selecting cards from advantageous \$50 Decks C + D (green + red cards). That is, there were significant block effects for each group: Male Experimental, $F(3, 207) = 13.97$, $p = 0.000$; Male Control, $F(3, 204) = 39.88$, $p = 0.000$; Female Experimental, $F(3, 204) = 16.22$, $p = 0.000$; Female Control, $F(3, 207) = 13.71$, $p = 0.000$.

In order to assess overall performance differences between the groups, a 2(gender) $\times$ 2(aroma condition) between subjects ANOVA was conducted. The results yielded no significance for the main effects of gender, $F(1, 274) = 3.092$, $p = .080$, or for aroma condition, $F(1, 274) = .552$, $p = .458$. However, as shown in Figure 3, there was a significant interaction, $F(1, 274) = 4.252$, $p = .040$, that was driven by the significant performance reduction by males in the experimental aroma condition. As predicted, males in the aroma condition chose significantly fewer advantageous Deck C + D cards ($M = 61.29$, $SD = 13.54$), than males in the control aroma condition ($M = 65.95$, $SD = 14.73$), $F(1, 137) = 3.77$, $p = .05$. No significant difference in the percentage of advantageous cards chosen was found between females in the control aroma condition ($M = 59.61$, $SD = 13.14$) vs. the female experimental aroma condition ($M = 61.80$, $SD = 13.90$), $F(1, 137) = .911$, $p = .342$. In addition, no significant difference emerged between males and females in the experimental aroma condition, $F(1, 137) = .047$, $p = .829$. However, males in the control aroma condition did choose significantly more advantageous cards from decks C + D (green and red cards) than females in the control aroma condition, $F(1, 137) = 7.18$, $p = .008$, i.e. the typical gender effect was replicated. Females chose equivalent numbers of cards in both conditions.

Thus, the most important results were twofold: (A) as in previous studies (Overman et al., 2004; Overman et al., 2006; Reavis & Overman, 2001), males in the control aroma condition chose significantly more advantageous \$50 Deck C and D (red + green) cards ($M = 65.95\%$) than did females ($M = 59.61\%$) and (B) this sex difference was eliminated in the experimental aroma condition: males *declined* from their baseline score and chose an equal number of advantageous cards ($M = 61.29\%$) as compared to females ($M = 61.8\%$). The females, however, did not change significantly from experimental aroma condition to neutral aroma control condition.

Since experiment 1 revealed that gender differences in card selection was driven by females' preference for the cards from deck B (yellow), several analyses were conducted for each of

the four decks. The results revealed that, in the control aroma condition, females ($M = 26.28$, $SD = 11.14$) chose more disadvantageous \$100 Deck B (yellow) cards than did males ($M = 21.25\%$, $SD = 10.27$), $F(1, 137) = 7.65$, $p = 0.006$. As we predicted, in the experimental aroma condition, there was no significant sex difference in choice of disadvantageous Deck B cards (yellow), $F(1, 137) = 1.46$, $p = 0.228$, (males $M = 23.62\%$, $SD = 9.83$; females $M = 25.94\%$, $SD = 12.60$). In the experimental aroma condition, males ($M = 15.06\%$, $SD = 6.48$) chose more disadvantageous \$100 Deck A cards (blue) than did females ($M = 12.47\%$, $SD = 7.02$), $F(1, 137) = 5.17$, $p = 0.025$. In addition, males in the experimental aroma condition also chose more disadvantageous \$100 Deck A (blue) cards than males in the neutral aroma control condition ($M = 12.80$, $SD = 6.89$), $F(1, 137) = 4.068$, $p = .046$. There were no significant sex differences in selection of the \$100 disadvantageous Deck A (blue) cards in the neutral aroma control condition nor were there any significant differences in other sex by deck comparisons, all p 's > 0.05 .

DISCUSSION OF EXPERIMENT 2

Our predictions were confirmed. IGT performance of males *declined* when they smelled and rated aromas during the task. Previous studies in our laboratory, as well as in others (Bolla et al., 2004), have found that under normal (non-aroma) conditions, males select advantageous \$50 Deck C + D (green + red cards) at approximately 70%. In the present study, when smelling and rating odorants, males selected significantly *fewer* \$50 advantageous cards ($M = 61.29\%$) than males in our previous research ($M = 69.8\%$) (Overman et al., 2004) ($t(100) = 2.44$, $p = 0.001$). In other words, when smelling aromas, males' performance resembled that of normative females in terms of selection of \$50 advantageous cards. However, unlike females' typical performance, the reduction of males' performance in the experimental aroma condition occurred from selecting significantly more \$100 disadvantageous Deck A (blue) cards rather than female preferred cards from deck B (yellow).

Another interesting finding of this study was that, in the neutral-aroma control condition, males chose only 65.94% advantageous cards as opposed to the typical control amount of approximately 70% as found in our previous studies. Though these two scores were not significantly different ($p > 0.05$), perhaps smelling even faint odors from the control vials slightly impaired performance via activating olfactory systems. Future studies might attempt to quantify the sensitivity of this effect in males.

GENERAL DISCUSSION

A recent meta-analysis of studies of the neural substrates of decision-making reveals differential involvement of orbitofrontal and dorsolateral PFC (Krain, Wilson, Arbuckle, Castellanos & Milham, 2006). While participating neural substrates vary depending on the nature of the decision being made, there is good agreement that ORB PFC activity is more likely to occur during tasks involving risk and DLPFC activity is more likely to occur during tasks involving ambiguity. The former possess an affective or "hot" component while the latter are less affectively laden or "cool". The IGT is thought to involve both processes: an affective or "hot" process based on magnitude of reward and a punishment and cognitive or "cool" evaluation of long-term gain or losses. These data are in agreement with behavioral studies that indicate individuals' pattern of card selection may reflect multiple decision-making processes (Brand, et al., 2006; Chiu, et al., 2008).

Our analyses of sex differences strongly suggest that gender predictably interacts with different decision-making styles. When tested for 200 trials on the IGT, females tended toward emotional processing of the IGT in that they favored, more than males, disadvantageous \$100 Deck B (yellow) cards of high frequency, high-value reward and low-

frequency punishment. In contrast, males tended toward more cognitive processing in that they *avoided* Deck B (yellow) cards and favored the cards from the two advantageous decks that resulted in long-term gain. Imaging evidence by Bolla et al., 2004) seemed to support this theory by showing increases in activation in medial ORB in females and DL PFC in males during the IGT.

Prior to the present study, we had reported data that suggested that reading PM dilemmas induced a shift in activation from ORB to DL PFC, and we suggested this was the basis for enhanced females' IGT performance. This fit with the notion of shifting females' decision-making processes from emotional to more cognitive.

However, in the present study, data failed to support a female enhancement in IGT performance that is associated with the deliberation of moral dilemmas. By contrasting and combining data, and increasing statistical power, the enhancement effect does not appear to be consistent. However, the data continue to support gender differences in performance such that males select more advantageous cards and female select more high-frequency, high-reward cards from Deck B (yellow). This suggests a dual process explanation for gender specific behavior, similar to that proposed by others (Stocco, et al., 2009).

In the present study, we also tested the "other half" of the dual-process hypothesis and putatively activated ORB via olfactory stimulation. By logically following a brain-behavior explanation of such findings (Bolla et al., 2004), we found that putative stimulation of olfactory cortex was associated with a decline in males' IGT performance to that of females. Furthermore, when smelling aromas, males selected as many disadvantageous cards from Deck B (yellow) as did females. To the extent such selection reflects more impulsive, emotional reaction, we can speculate that activation of ORB in males rendered their decision-making more affective and less cognitive (Kringelbach, et al., 2005). Female's IGT performance was unchanged by smelling aromas. It is unlikely that the male effect was due to some specific action of any given scent because 20 distinct odors were employed and smelled only once. Rather, we speculate that the male effect was due to a general and consistent stimulation of olfactory cortex in ORB.

These results draw attention to differences in various processes involved in decision-making, differences in decision-making in males and females, and multiple neural mechanisms involved in decision-making.

Caveats

There are limitations of the present research. First the data are based solely on overt behavior and are derived from a single decision-making task. Our speculations require future support from other paradigms, particularly imaging procedures. In addition, there are many types of decisions, ethics, and moralities that, most certainly, are not represented by a few, simple neural circuits, but rather by multiple and highly dynamic networks. Our findings should not be generalized to all decisional behavior. With regard to multiple neural networks, our research tentatively suggests that at least a portion of the neural systems and behavioral outcomes can be affected by the environmental contexts in which they are activated.

Secondly, we cannot entirely rule out a "social" explanation for our findings. Most of the experimenters were female. This may have somehow interacted with aromas (perhaps suggestive of perfumes?) and differentially affected males' performance. We are currently exploring this possibility.

Finally, there should be a note about the use of different versions of the IGT. Numerous versions of this task have been employed. Some follow the original paradigms (Bechara, et al., 1994), some follow revised versions in which rewards and punishers escalate through out the task (Bechara, et al., 2000), some use “in house” versions (Lin et al., 2007; Paulus, et al., 2004), and some published studies do not specify the detailed procedures of the task. Also, many published IGT studies employ only 100 trials, despite evidence that subjects continue to learn and improve through at least 200 trials. These studies are not measuring the entire decision learning process. Additionally, many published reports have included only males or have not analyzed for gender differences when both males and females participated. Our results, and those of others (Bolla, 2004; Stout, et al., 2005) point out the need for representation of females in decision-making research. Caution should be exerted, in comparing decision-making studies that use different procedures, incomplete statistical analyses, and differential inclusion of males.

APPENDIX I

Essential oil aromas

1. Blue tansey: *tanacetum annum*
2. Frankinsense: *boswellia carteii*
3. Black spruc : *pica mariana*
4. Vetiver: *andropogon muricatus*
5. Palmarosa: *cymbopogon martini* var *mode*
6. Ginger: *zingibar officinale*
7. Clary sage: *salvia sclarea*
8. Patchauli: *pogostemon patchouli*
9. Geranium: *pelargonium graveolen*
10. White thyme: *thymus zygus*
11. Basil: *ocimum Basiscum*
12. Orange: *citrus sinensis*
13. Lemongrass: *cymbopogon flexosus*
14. Lemon: *citrus limon*
15. Scotch pine: *pinus sylvestris*
16. Rose: *rosa borboniana*
17. Tea tree: *melaleuca alternifolia*
18. Sandlewood: *santalum album*
19. Pinkgrapefruit: *citrus paradisi*
20. Rosemary: *rosmarinu officinalis*

References

- Bechara A, Damasio H, Damasio A. Emotion, decision-making and the orbitofrontal cortex. *Cerebral Cortex*. 2000; 10:295–307. [PubMed: 10731224]

- Bechara A, Damasio A, Damasio H, Anderson SW. Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition*. 1994; 50:7–15. [PubMed: 8039375]
- Bechara A, Damasio H, Tranel D, Damasio AR. Deciding advantageously before knowing the advantageous strategy. *Science*. 1997 Feb 28;275:1293–1295. [PubMed: 9036851]
- Bolla KI, Eldreth DA, Matochik JA, Cadet JL. Sex-related differences in a gambling task and its neural correlates. *Cerebral Cortex*. 2004; 14:1226–1232. [PubMed: 15142963]
- Bowman CH, Evans C, Turnbull OH. Artificial time constraints on the Iowa Gambling Task: The effects on behavioral performance and subjective experience. *Brain and Cognition*. 2005; 57:21–25. [PubMed: 15629209]
- Brand M, Labudda K, Markowitsch HJ. Neuropsychological correlates of decision-making in ambiguous and risky situations. *Neural Networks*. 2006; 19:1266–1276. [PubMed: 16942857]
- Bromley S, Doty R. Odor recognition is better under bilateral than unilateral test conditions. *Cortex*. 1995; 31:25–40. [PubMed: 7781318]
- Carmichael ST, Clugnet MC, Price JL. Central olfactory connections in the the macaque monkey. *Journal of Comparative Neurology*. 1994; 346:403–434. [PubMed: 7527806]
- Chiu, Lin, Huang, Lin, Lee, Hsieh. Immediate gain is long-term loss: Are there foresighted decision makers in Iowa Gambling Task? *Behavioral and Brain Functions*. 2008; 4:13. [PubMed: 18353176]
- Clark L, Manes F, Antoun N, Sahakian BJ, Robins TW. The contributions of lesion laterality and lesion volume to decision-making impairment following frontal lobe damage. *Neuropsychologia*. 2003; 41:1474–1483. [PubMed: 12849765]
- Crone E, Bunge S, Latenstein H, van der Molen. Characterization of childrens' decision-making: sensitivity to punishment frequency, not task complexity. *Child Neuropsychology*. 2005; 11:245–263. [PubMed: 16036450]
- Damasio, AR. *Descarte's Error*. New York: G Putnam's Sons; 1994.
- Doty R, Shaman P, Dann M. Development of the University of Pennsylvania Smell Identification Test: A standardized microencapsulated test of olfactory function. *Physiology and Behavior*. 1984; 32:489–502. [PubMed: 6463130]
- Doty R, Stern M, Pfeiffer C, Gollomp S, Hurtig H. Bilateral olfactory dysfunction in early stage treated and untreated idiopathic Parkinson's disease. *Journal of Neurology, Neurosurgery, and Psychiatry*. 1992; 55:138–142.
- Elliot R, Dolan RJ, Frith CD. Dissociable functions in the medial and lateral orbital orbitofrontal cortex: evidence from human neuroimaging studies. *Cerebral Cortex*. 2000; 10:308–317. [PubMed: 10731225]
- Fellows LK, Farah M. Different underlying impairments in decision-making following ventromedial and dorsolateral frontal lobedamage in humans. *Cerebral Cortex*. 2005; 15:58–63. [PubMed: 15217900]
- Greene JD, Sommerville RB, Nystrom LE, Darley JM, Cohen JD. An fMRI investigation of emotional engagement in moral judgment. *Science*. 2001 Sep 14;293:2105–2108. [PubMed: 11557895]
- Greene JD, Haidt J. How (and where) does moral judgment work? *Trends in Cognitive Sciences*. 2002; 6(12):517–523. [PubMed: 12475712]
- Greene JD, Nystrom LE, Engell AD, Darley JM, Cohen JD. The neural bases of cognitive conflict and control in moral judgment. *Neuron*. 2004; 44:389–400. [PubMed: 15473975]
- Jollant F, Bellivier F, Leboyer M, Astruc B, Torres S, Verdier R, Casteinau D, Malafosse A, Courtet P. Impaired decision making in suicide attempters. *American Journal of Psychiatry*. 2005; 162:304–310. [PubMed: 15677595]
- Jones-Gotman M, Zatore RJ. Odor recognition memory in humans: Role of right temporal and orbitofrontal regions. *Brain and Cognition*. 1993; 22:182–198. [PubMed: 8373572]
- Krain AL, Wilson AM, Arbuckle R, Castellanos FX, Milham MP. Distinct neural mechanisms of risk and ambiguity: A meta-analysis of decision-making. *NeuroImage*. 2006; 32:477–484. [PubMed: 16632383]
- Kringlebach M. The human orbitofrontal cortex: Linking reward to hedonic experience. *Nature Reviews Neuroscience*. 2005; 6:691–702.

- Lin CH, Chiu YC, Lee PL, Hsieh JC. Is deck B a disadvantageous deck in the Iowa Gambling Task? *Behavioral and Brain Functions*. 2007; 3:16. [PubMed: 17362508]
- Manes F, Sahakian B, Clark L, Rogers R, Antoun N, Aitken M, Robins T. Decision-making processes following damage to the prefrontal cortex. *Brain*. 2002; 125:624–639. [PubMed: 11872618]
- O'Doherty J, Kringelbach ML, Rolls ET, Hornak J, Andrews C. Abstract reward and punishment representations in the human orbitofrontal cortex. *Nature Neuroscience*. 2001; 4:95–102.
- Ongur D, Price JL. The organization of networks within the orbital and medial prefrontal cortex of rats, monkeys and humans. *Cerebral Cortex*. 2002; 10:206–219. [PubMed: 10731217]
- Overman WH. Sex differences in early childhood, adolescents and adulthood on cognitive tasks that rely on orbital prefrontal cortex. *Brain and Cognition*. 2004; 55:133–146.
- Overman WH, Frassrand K, Ansel S, Trawalter S, Bies B, Redmond A. Performance on the IOWA card task by adolescents and adults. *Neuropsychologia*. 2004; 42:1838–1851. [PubMed: 15351632]
- Overman WH, Graham L, Redmond A, Eubank R, Boettcher L, Samplawski, Walsh K. Contemplation of moral dilemmas eliminates sex differences on the Iowa Gambling Task. *Behavioral Neuroscience*. 2006; 120:817–825. [PubMed: 16893287]
- Paulus MP, Feinstein JS, Simmons A, Stein MB. Anterior cingulate activation in high trait anxious subjects is related to altered error processing during decision making. *Biological Psychiatry*. 2004; 55:1179–1187. [PubMed: 15184037]
- Price, JL. Olfactory system. In the human nervous system. Paxinos, G., editor. Academic; San Diego: 1990. p. 979-1001.
- Price, JL. Connections of orbital cortex. In: Zald, DH.; Rauch, SL., editors. *The Orbitofrontal Cortex*. New York: Oxford University Press; 2006. p. 39-550.
- Reavis R, Overman WH. Adult sex differences on a decision making task previously shown to depend on the orbital prefrontal cortex. *Behavioral Neuroscience*. 2001; 115:196–206.
- Rolls E. the functions of the orbitofrontal cortex. *Brain and Cognition*. 2004; 55:11–29. [PubMed: 15134840]
- Rolls ET, Kringelbach ML, de Araujo IET. Different representations of pleasant and unpleasant odours in the human brain. *European Journal of Neuroscience*. 2003; 18:695–703. [PubMed: 12911766]
- Royet J, Hudry J, Zald D, Godinot D, Gregoire M, Lavenne F, Costes N, Holley A. Functional neuroanatomy of different olfactory judgements. *Neuroimage*. 2001; 13:506–519. [PubMed: 11170816]
- Royet J, Plailly J. Lateralization of olfactory processes. *Chemical Senses*. 2004; 29(8):731–745. [PubMed: 15466819]
- Sensonics, Inc. P.O. Box 112 Haddon Heights, N.J. 08035
- Stocco A, Fum D, Napoli A. Dissociable processes underlying decisions in the Iowa Gambling Task: a new integrative framework. *Behavioral and Brain Functions*. 2009; 5:1, 1–12. [PubMed: 19121215]
- Stout JC, Rock SL, Campbell MC, Busemeyer JR, Finn PR. Psychological processes underlying risky decisions in drug abusers. *Psychology of Addictive Behaviors*. 2005; 19(2):148–157. [PubMed: 16011385]
- Tranel D, Bechara A, Denenberg NL. Asymmetric functional roles of right and left ventromedial prefrontal cortices in social conduct, decision-making and emotional processing. *Cortex*. 2002; 38:589–612. [PubMed: 12465670]
- Yechiam E, Stout JC, Busemeyer JR, Rock SL, Finn PR. Individual differences in the response to forgone payoffs: An examination of high functioning drug abusers. *Journal of Behavioral Decision Making*. 2005; 18:97–110.
- Zald, DH.; Rauch, SL., editors. *The orbitofrontal cortex*. New York: Oxford University Press; 2006.

Research Highlights

- Males outscore females on the Iowa Gambling Task (IGT) perhaps due to differential regional prefrontal cortical activation by males and females during the task. PET imagery indicates increased activation in dorsolateral (DL) prefrontal cortex (PFC) in males and in medial orbital (ORB) PFC in females.
- A recent study reported that females' scores were elevated to the level of males' by having them deliberate moral dilemmas during the IGT. This was presumably due to a relative shift in PFC activation from medial ORB PFC to DL PFC areas.
- In the present study, by adding new participants and by combining results from previous studies, we failed to find a significant effect of deliberating dilemmas prior to or during the original IGT (original version) performance.
- However, the typical gender effect was replicated, as was the females' preference for cards from Deck B. The lack of dilemma enhancement fails to support our previous suggestion of increasing activation in DL during the task.
- We also investigated whether activation of ORB (also olfactory cortex) would change IGT performance. When smelling novel aromas during the IGT, males' performance was reduced to the level of females whose performance was unchanged.
- These findings suggest that activation of emotional neural substrates might alter the dual cognitive (DL)/emotional (ORB) circuits that normally interact during decision-making.

Figure 1. Percentage of \$50 advantageous Deck C + D) (red + green) cards selected across 200 trials of the IGT by males and females when three dilemma types were read prior to performance of the task. Vertical bars represent SEM

Figure 2. Percentage of \$50 advantageous Deck C + D (red + green) cards selected by males and females as a function task condition (reading dilemmas before and after the IGT vs. IGT only). Asterisks indicate significant gender differences. Vertical bars represent SEM.

Figure 3. Percentage of \$50 advantageous Deck C+D (red + green) cards selected by males and females when smelling no aromas or smelling aromas. Asterisk indicates a significant gender difference. Vertical bars represent SEM.