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The role of anxiety in decision-making

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Over the past decade, many studies have shown that individuals with reduced sensitivity for risk due to traumatic brain injury in orbital parts of the prefrontal cortex tend to ignore the long term outcomes of their behavioral actions (the same holds true for individuals with socio-/psychopathy). Instead, these individuals merely base decisions on anticipated immediate gains, similar to impulsive choice in children. The Iowa gambling task has been designed specifically to measure this behavioral tendency. We used this task to investigate a state opposite to that of impulsiveness and carelessness, namely enhanced anxiety and risk intolerance. We expected beneficial effects on decision-making, especially since high anxiety in both healthy populations and patients with anxiety disorders has been linked with enhanced activation of orbitofrontal cortex. Our most important finding is that intolerance towards uncertainty is indeed positively correlated with overall performance on the Iowa gambling task in a sample of adults as well as with anxiety in a sample of children. Results illustrate the protective functions of anxiety and risk aversion, and their positive long-term effects on decision-making. These motives seem to enable individuals to better consider future consequences of their actions, and to switch from previously reinforced behaviors to alternative behaviors when contingencies change.

Key words: anxiety, gambling, decision-making, orbitofrontal, prefrontal, risk-seeking

Anxiety is a subjectively rather unpleasant emotional state accompanied by typical physiological symptoms, such as increased heart rate, respiration rate, and enhanced electrodermal reactivity. It is usually accompanied by concerns and worries as well as the desire to withdraw or hide away or otherwise protect oneself, although many different forms exist. For some individuals, feelings of anxiety can become so predominant and overwhelming that medical and psychological treatment is needed to help gain control and manage everyday life.

On the other hand, in view of evolution, anxiety is a very important and life-saving emotion that prepares body and cognition for adaptive actions and reactions. It is only in our modern industrial societies, where acute threats to life rarely exist in a direct form that can be tackled with physical reactions, that anxiety becomes a psychological and medical problem, as Robert Sapolsky (1998) has stressed in his book "Why Zebras Don't Get Ulcers". It is therefore often forgotten, particularly amongst clinicians and patients, but also amongst researchers, that anxiety is an adaptive, protective behavioral motive that influences our choices and actions in a beneficial way.

Studying conditions of lacking or pathologically reduced anxiety can be vital for understanding the functional role of anxiety. Among them are sociopathy (Hare, 1965; Hare, 1998; Flor, Birbaumer, Hermann, Ziegler, & Patrick, 2002) and particular forms of brain damage, particularly individuals with traumatic injury to the orbitofrontal cortex (OFC), a structure that is known to both control and release fear reactions depending on context and higher cognitive evaluation (Kringelbach & Rolls, 2004; Wallis, 2007).

A vital description of such cases has been given by Damasio (1994): The patients show impulsiveness, irritability, reduced emotion control, lack of tact and sensitivity, lack of steadiness and reliability, difficulties in planning and goal-related behavior. As the OFC is one of the last brain structures to mature during ontogenesis, children and adolescents often display behaviors that are reminiscent to that of these patients (Spear, 2000).

Research investigating the underlying cognitive and brain dynamics has stressed the fact that patients with damage to the OFC are less able or less willing than healthy individuals to make predictions about future rewards and

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punishments, and instead take into account only immediate outcomes of their actions when making decisions. This tendency has been termed "myopia for the future" (Bechara, Tranel, & Damasio, 2000), and seems to be accompanied by a reduced ability to switch action plans in accordance with long-term experiences (Fellows & Farah, 2005). That is, the patients choose behavioral options that appear advantageous at first sight, with little regard for the potential risks and long-term consequences involved, which leads to misinvestment and aimlessness, alongside massive social problems.

A behavioral task that has been designed specifically to measure the described cognitive deficit is the Iowa gambling task (Bechara, Damasio, Damasio, & Anderson, 1994). The task is a card playing game in which subjects are asked to draw cards from four decks in order to win points. In the original version of the task, two decks of cards (A and B) are associated with 100 points each while the other two decks contain cards that win only 50 points (C and D). However, what the player needs to learn over a number of trials is that relatively many of the cards from the 100 point decks are also associated with significant losses, in such a way that the long term balance is negative if a player continues to draw from those decks (on average, -25 points per card). In contrast, the cards from the 50 point decks are associated with fewer (or less significant) losses such that the long-term expectancy value is positive (25 points per card). This means that although it seems advantageous at first sight to draw from the 100 point decks (A and B), further experiences should tell a player that they can only win points if they draw from the 50 point decks (C and D). They therefore have to inhibit the temptation to draw from those decks and instead choose cards from the other two decks in order to maximize their balance. A computerized version of the task exists that entails some more dynamic variation in the payoffs (Iowa Gambling Task ™, Psychological Assessment Resources Inc., Lutz, FL).

Bechara, Damasio, Tranel, and Damasio (1997) have hypothesized that patients with damage to the ventromedial prefrontal (or medial orbitofrontal) cortex are unable to learn the Iowa gambling task because they are missing the intact brain structures needed to process signals from the body periphery and/or from other brain structures like the amygdala informing them about hidden or future risks involved in choice options. They have based this hypothesis on the observation that patients with damage to the ventromedial prefrontal cortex fail to develop electrodermal skin reactions when drawing cards from the risky decks (C and D). In a sense, the patients are lacking sensitivity for risk or some form of predictive anxiousness when making their choices. Interestingly, despite their disadvantageous behavior, about half of the patients do have conscious insight into the rules of the game, and can report on what chances the decks involve (Bechara et al., 1997). However, when asked why they draw from the risky decks nonetheless, they answer that they just do not care. Other researchers have found similar deficits in patients characterized by social and impulse control deficits such as substance abuse, pathological gambling, and psychopathy (Forbush et al., 2008; Hanson, Luciana, & Süllwold, 2008; van Honk, Hermans, Putman, Montagne, & Schutter, 2002).

From a descriptive point of view, the characteristics of those patients is the opposite of what would be expected from individuals with heightened anxiety, at least with regards to free floating anxiety that has no specific trigger (like specific phobias). Individuals with these forms of anxiety care more about risks and potential losses than do healthy people; they worry enormously about making the right decisions, and they are highly concerned about what the future will entail, a tendency that has been described as an attentional bias towards threat by modern theories of anxiety (Clark, 1986; Ehlers, Margraf, Davies, & Roth, 1988; McNally, 1994, 1995, 1997; Williams, Watts, MacLeod, & Mathews, 1997). Clinical forms such as Generalized Anxiety Disorder (GAD, APA, 1994) are further characterized by prevailing somatic symptoms, including increased heart rate, sweating, headaches, sleeplessness, and muscle tension. In specifying these criteria, Dugas, Gagnon, Ladouceur, and Freeston (1998) described intolerance of uncertainty (IU), beliefs about worries, poor problem orientation, and cognitive avoidance as main features of GAD. IU was found as particularly useful in discriminating GAD patients from unaffected individuals. Thus, these patients experience an abundance of worries about the future as well as somatic signals relating to predicted risk and danger, and can therefore be hypothesized to display different decision-making patterns. Specifically, it should be easier for them to perceive, consider, and integrate somatic signals with expectations about future outcomes in the decision-making process, which should help them to avoid choice options that are disadvantageous in the long run and therefore lead to better outcomes in the Iowa gambling task. Such a hypotheses is indirectly supported by data from recent imaging studies suggesting that patients with anxiety disorders show abnormal activation patterns in OFC (Domschke et al., 2008; Monk et al., 2006; Monk et al., 2008). The patients tend towards higher activation or higher involvement of OFC regions during task performance, contrary to patients with OFC lesions or sociopathy. Healthy individuals under induction of "worry" show the same tendency towards heightened activation of orbitofrontal structures (Hoehn-Saric, Lee, McLeod, & Wong, 2005) as do individuals who are at high risk for anxiety and depression when reading negative emotional words (Wolfensberger et al., 2008). Incidentally, these results confirm the notion that there is a continuum between normal (state) and pathological (trait) forms of anxiety, in line with most modern theories and findings (e.g., Endler & Kocovski, 2002; Hansell & Damour, 2008).

Direct empirical evidence about the impact of anxiety on decision-making processes as assessed by the Iowa gambling task is lacking. Two studies have investigated the influence of depression, which is often comorbid with anxiety, and found conflicting results, namely superior performance of the patients in one (Smoski et al., 2008) and inferior performance in the other study (Must et al., 2006) Preliminary studies from our own laboratory in patients with panic disorder did not find any differences between patients and healthy controls (Guse, 2006; Wischniewski, 2006); however, these studies did not use the computerized version of the task and therefore may not be comparable to the other studies. A very recent study by Miu, Heilman, and Houser (2008) found increased somatic activity in individuals with high trait anxiety, as expected, but this activity was ambiguous as it did not specifically signal risk, which led to impaired performance on the Iowa gambling task by these individuals compared to individuals with low trait anxiety, contrary to our above reasoning. However, another study (Preston, Buchanan, Stansfield, & Bechara, 2007) in which speech anxiety was induced prior to testing performance on the Iowa gambling task did find that that this form of stress enhanced performance on the task, but only in female participants (while the opposite was true for male participants). Yet another study by Garon, Moore, & Waschbusch (2006) found a sample of anxious and depressed children with ADHD to learn the Iowa gambling task more easily than nondepressed and nonanxious children with ADHD. Thus, a number of results point towards enhanced performance on the task when anxiety is involved, although almost as much evidence for the opposite hypothesis exists.

While superior performance of individuals with high anxiety could be easily explained in the above theoretical terms, what could be the reason behind *inferior* performance of individuals with high anxiety? Perhaps it is too simplistic to assume that high somatic activity and heightened activation of OFC will lead to enhanced risk perception and more advantageous decision-making. After all, the peripheral and the central nervous systems do not function like a muscle whose degree of activation determines degree of contraction and thereby motor performance. Instead, their activity is based on neural network processing whose performance relies on efficacy and reliability of information transfer and integration. Thus, any deviation from normal, be it hyper- or hypofunctional, will lead to disturbances in performance.

A theory that favours this point of view is the theory of psychobiology by Lungwitz (1955; Becker, 1993), a German psychiatrist who has sometimes been described as the unknown founder of Cognitive Behavioral Therapy. He described clinical anxiety as a consequence of hypertrophy of specific neuronal cells which mediate the feeling of “being cornered, beset, of compulsion, of inhibition, of astonishment, of defiance, of withdrawal, shame, shyness, carefulness, care, etc.” (Becker, 1993, p. 41). In his conception, hypertrophy of those cells - today probably better described as ‘hyperactivity’ (e.g., excessive firing, lower firing thresholds) - leads to malfunctioning (not superior functioning) of the entire anxiety reflex system, including cognition, feeling, and bodily reactions. The condition lets the patients’ cognitive styles and attitudes towards the world regress towards a more self-absorbed and less sophisticated way of thinking that Lungwitz described as ‘infantilistic’, as if it were immature or underdeveloped. Patients with anxiety disorder are therefore expected to think and behave similarly to children, which may or may not fit with today‘s view of overactive OFC in anxiety and immature OFC in children. Clearly, Lungwitz had to be lacking much of today’s knowledge about neural information processing, but at a very functional-descriptive level, his conception describes a testable hypothesis about parallel thinking styles in children and patients with anxiety disorders (c.f., Kalin, Shelton, & Davidson, 2007).

Lungwitz further proposed that neuroses of childhood do not differ in principle from neuroses of adults: According to his expectations, neurotic children with high anxiety show a yet more “infantilistic” and evolutionarily “primitive” thinking style than do their healthy peers because of their underdeveloped anxiety reflex systems (see Becker, 1993, p. 107). Thus, not only do the effects of neurotic anxiety and young age lie on the same dimension (as they both rely on immature “reflex systems”), they are also presumed to have additive effects. When applied to the Iowa gambling task, the theory would predict that neurotically anxious children perform inferior to both healthy children and adults with anxiety disorders, who in turn perform inferior to healthy adults.

The present study tested the impact of anxiety on performance in the Iowa gambling task in children and adults with varying degrees of anxiety ranging from low to clinically relevant using correlational analyses. We included a number of selected personality traits and intellectual abilities in the analyses, and controlled for confounding variables such as age, depression, and gender by statistical means. We preferred this dimensional approach to a between-groups design as we find it more powerful and illustrative and less dependent on sample sizes than subgroups. The approach is also theoretically more appropriate as modern theories of anxiety (Endler & Kocovski, 2002; Hansell & Damour, 2008) as well as the theory of psychobiology by Lungwitz (1955) hold a dimensional perspective onto mental illnesses assuming a continuum between healthy and ill rather than a categorical one with discrete boundaries.

METHODS

Participants

Thirty adults (21 female, mean age: 48 years, range 23-80) were investigated. They were recruited via newspaper advertisements, local self-help groups, local psychotherapists and local clinical institutions. The newspaper ad asked for volunteers who experience high degrees of worry and general anxiety. Additionally, seven volunteers without anxiety and worries participated. Participants were excluded from participation if they had clinically relevant depression. One participant was dropped after her data were acquired. This person had a BDI score of 37 and was a clear outlier (more than 3 *SD* above the mean). In addition, she did not learn the gambling task at all; she started off with a balance of approximately 0 in the first block of 20 trials and ended up drawing cards only from "bad" decks over the last 40 trials (resulting in a maximally negative balance of -20 in the two final blocks); suggesting to us that she had not been able or willing to follow the instructions.

All participants received reimbursement of their travel expenses plus the money they won in the gambling game (ranging from 5 € through 20 €).

The children sample consisted of 67 children (33 female, mean age 10.43 years, range 7-14) recruited via local communities and sports groups while no specific anxiety levels were targeted. Children were allocated to two parallel groups to perform the two versions of the gambling task in different order. The group which played the original version first consisted of 34 children (18 female, mean age 10.35, range 7-14), the other group consisted of 33 children (17 female, mean age 10.52, range 7-14). The children were investigated after written informed consent had been obtained from their parents. The parents of the children received an expense allowance of 5 €. After performance, the children were offered to choose a little gift from one of three boxes which contained little toys. The three boxes were graded according to the amount of points won in the gambling game.

Materials

The adults played a computer game that we developed in accordance with the computerized Iowa gambling task. Electrodermal activity (results not reported) was taken using the "Kölner Mini Vitaport System" (Ingenierbüro Becker, Karlsruhe, Germany). Anxiety levels and risk aversion was measured using a German Version of the Intolerance of Uncertainty Scale Short Form (IUS-12; Carleton, Norton, & Asmundson, 2007), provided by the specialized GAD outpatient clinic at the University of Dresden, the German Version of the Beck-Depression Inventory II (Hautzinger, Keller, & Kühner, 2006) the German Versions of the Penn State Worry Questionnaire (PSWQ, Meyer, Miller, Metzger, & Borkovec, 1990) provided by Stöber (1995), the Worry Domain Questionnaire (WDQ, Tallis, Eysenck, & Mathews, 1992), German short version (Stöber & Joormann, 2001), and the German version (Ehlers, 1986) of the Anxiety Sensitivity Index (ASI, Reiss, Peterson, Gursky, & McNally, 1986).

The children played two different versions of the computerized version of the Iowa gambling task. The first version was a computerized adaptation of the original task. To make it more appropriate for children, the original amounts of gains and losses were divided by 25 so that the amounts were reduced, but the relations were the same. Unlike the adults, children were not only asked to make as many points as they could, they were also given a cover story in which they were asked to help a little magician who needed some magic balls to achieve his witcheries. Reward values of 4 (decks A and B) and 2 points (decks C and D), and punishment values ranging from 0-50 points for disadvantageous ("bad") desks and 0-10 points for the advantageous ("good") desks were administered. In the second version we used a shuffled version of the IGT as described by Fellows and Farah (2005) which was adapted for children in the same way. In this shuffled version, significant losses occur earlier than in the original version to prevent the establishment of initial preferences for bad decks. With this version, Fellows and Farah (2005) found no performance deficits in patients suffering from OFC lesions. Presenting this shuffled version to children should thus enable us to differentiate between the effect of immature OFC and the effect of anxiety *per se* on task performance.

Rewards and punishment values were displayed for 6 sec after which participants could choose the next deck. The total balance was presented at the bottom of the screen in addition to the current trial outcome. Below the balance, a winning bar was shown that turned to green when the balance was positive and to red when it was negative. The bar grew in either direction, left or right, depending on the number of points won or lost. After 100 trials, the program ended and the overall outcome was displayed.

Anxiety levels and risk aversion was measured using the Kinder Angst Test II (KAT II; Thurner & Tewes, 2000). Other tests that were completed by the children in order to obtain a gross estimate of intellectual capabilities were the Connect-the-Numbers Test (Zahlen-Verbindungs-Test, ZVT, Oswald & Roth,1997) and the Digit Span Task measuring a form of working memory (WISC III), both taken from the Wechsler Intelligence Scale for Children (Wechsler, 1991).

Procedures

After having signed the informed consent, adult participants were interviewed about their symptoms using free questionnaires and a short version of a standardised German diagnostic interview (Mini-DIPS; Margraf, 1994), and also filled out the questionnaires. Before the experiment started, electrodes were placed on subjects' palms and connected to the Mini-Vitaport. Finally, participants were shown the gambling task on the computer. They were instructed to try to make as many points as possible. One session took approximately 90 minutes.

The procedure varied for the children only in that the children were not interviewed before the experiment and that they played either one of the two versions of the gambling task described above. After task completion the children filled out the questionnaires.

RESULTS

Descriptive statistics of all dependent variables can be found in Table 1. A t-test indicated that children's overall performance was similar to that of adults ($t(94)=1.21$, n.s.). Note, however, that the task versions may not be directly comparable as their task version was slightly modified (and made simpler) to help them understand the instructions.

For both samples, to investigate the relationship between the various cognitive facets of anxiety and decision-making, we computed correlations between the psychodiagnostic questionnaire measures and the total performance score of the Iowa gambling task (i.e., number of cards drawn from advantageous decks [C or D] minus number of cards drawn from disadvantageous decks [A or B] across all 100 trials). As the adult sample was rather small, we additionally calculated non parametric correlations (Spearman's Rho). However, because results were almost identical, we report only Pearson's r here. Potential confounds such as age and gender were taken into account as indicated.

For the adults, we did not find any significant correlation between PSWQ, ASI or BDI and the total performance score in the Iowa gambling task, but intolerance of uncertainty (IUS) did correlate positively with total gambling performance score ($r=.377$, $N=29$, $p<.05$), as did the WDQ ($r=.404$, $N=29$, $p<.04$). However, most of the other correlations turned out significant as well when gender differences were taken into account by means of a covariate, as male participants had significantly higher scores ($M=24.2$, $SD=24.17$) than did women ($M=-1.90$, $SD=24.27$; $t(27)=2.69$, $p<.05$). Now there were significant correlations between the total performance score in the Iowa gambling task and PSWQ ($r=.397$, $df=26$, $p<.04$), WDQ ($r=.377$, $df=26$, $p<.05$), ASI

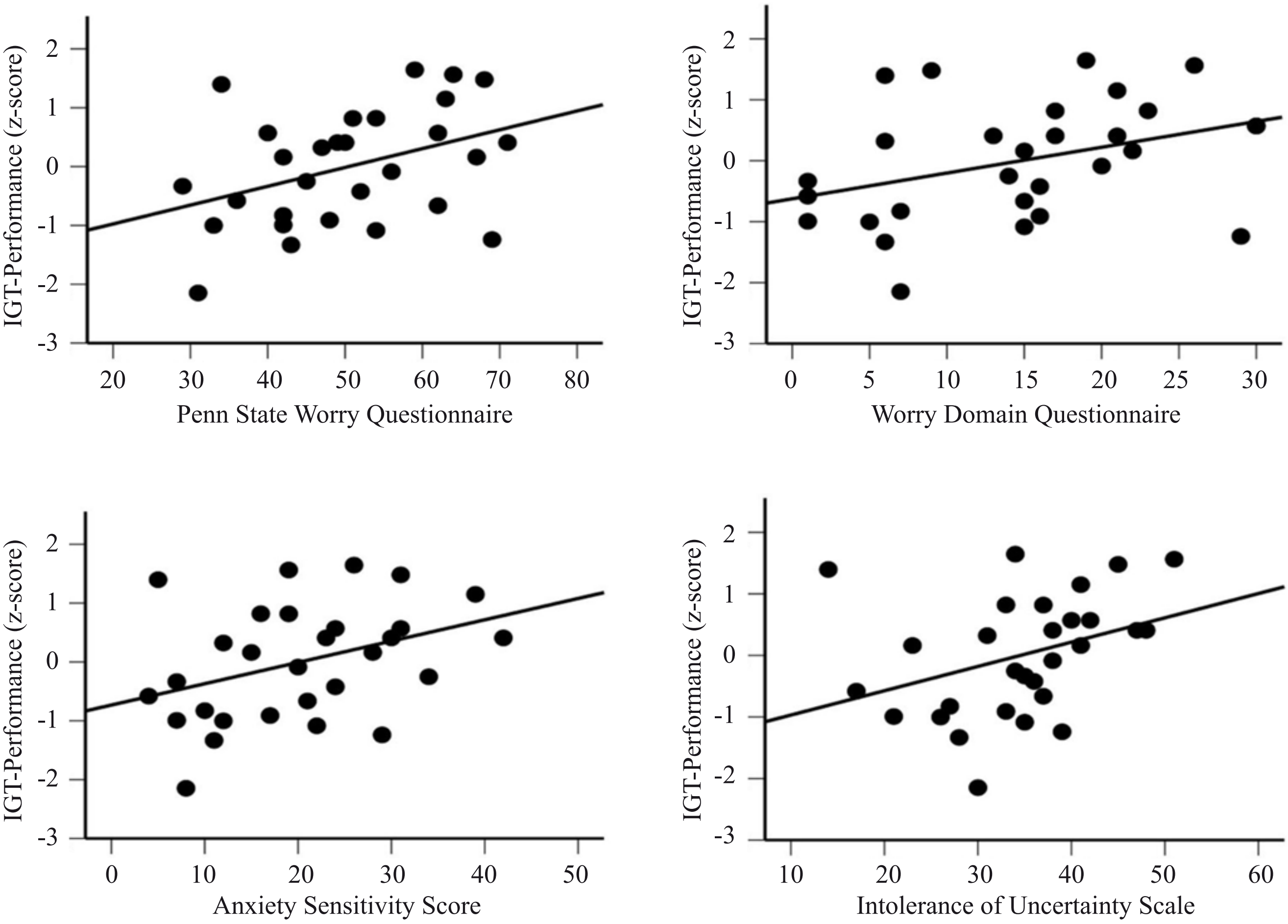
Table 1
Descriptive statistics of the dependent measures for the two samples

Adult Sample (*N*=29)	Mean (*SD*)
Total Gambling Score	6.21 (26.79)
Anxiety Sensitivity Score (ASI)	20.21 (10.23)
Beck Depression Inventory II (BDI)	11.86 (7.84)
Worry Domain Questionnaire (WDQ)	14.76 (8.66)
Penn State Worry Questionnaire (PSWQ)	50.44 (12.16)
Intolerance of Uncertainty Scale Short Form (IUS-12)	34.52 (8.87)
Children Sample (*N*=67)	
Sample: Original Version (*N*=34)	
KAT Anxiety Score	3.59 (2.72)
Total Gambling Score	2.53 (13.79)
WCST digit span forward	6.56 (1.77)
WCST digit span backward	5.29 (1.71)
WCST block span forward	8.41 (1.51)
WCST block span backward	8.67 (1.62)
Connect-The-Numbers (ZVT)	102.21 (16.92)
Sample: Shuffled Version (*N*=33)	
KAT Anxiety Score	3.82 (2.74)
Total Gambling Score	-4.30 (31.80)
WCST digit span forward	6.67 (2.04)
WCST digit span backward	5.57 (1.62)
WCST block span forward	8.72 (1.72)
WCST block span backward	8.15 (1.58)
Connect-The-Numbers (ZVT)	102.51 (19.90)

Table 2
Correlation matrix for the adult group

	Total performance in the Iowa gambling task	Age	Gender	PSWQ	WDQ	ASI	IUS_D_12
Age	.098 *.057*	–					
Gender	-.459(*)	-.106	–				
PSWQ	.329 *.397(*)*	.220 *.277*	.0500	–			
WDQ	.404(*) *.377(*)*	.120 *.106*	-.159	.649(**) *.666(**)*	–		
ASI	.309 *.378(*)*	.049 *.056*	.058	.729(**) *.728(**)*	.643(**) *.662(**)*	–	
IUS_D_12	.377(*) *.359*	.178 *.167*	-.131	.721(**) *.735(**)*	.673(**) *.666(**)*	.740(**) *.755(**)*	–
BDI_II	.237 *.385(*)*	.458(*) *.494(**)*	.210	.468(*) *.469(**)*	.332 *.379(*)*	.535(**) *.536(**)*	.508(**) *.552(**)*

Note. Numbers in italics reflect the correlations after controlling for gender effects. All correlation coefficients are Pearson's r. Significance (2-tailed): $^{**}p<.01$, $^{*}p<.05$.



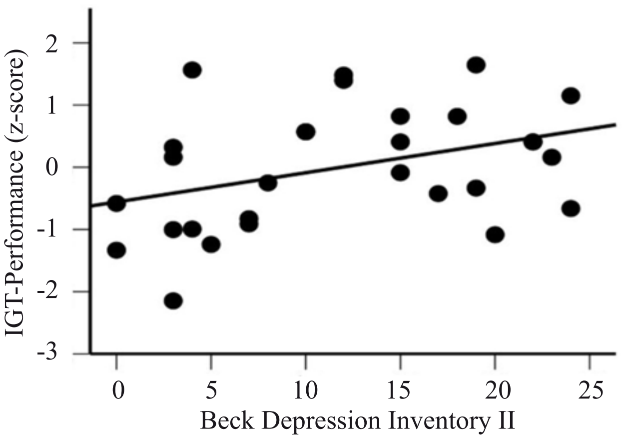


Figure 1. Correlations between the questionnaire scales measuring anxiety and depression and performance in the Iowa gambling task. Note that gambling scores have been z-transformed to eliminate gender differences

(*r*=.378, *df*=26, *p*<.05), BDI II (*r*=.385, *df*=26, *p*<.05) and a trend for the IUS (*r*=.359, *df*=26, *p*=.06). This means that anxiety and depression did indeed enhance gambling performance when gender differences were taken into account. The correlations are shown in Figure 1.

For the children we found a modest correlation (*r*=.234, *N*=67, *p*=.057), between the KAT anxiety test score and total Iowa gambling performance score when we combined both versions. However, when looking at the original version alone, the significance disappeared (*r*=-.144, *N*=34, n.s.). In contrast, when looking at the shuffled version alone, the correlation became stronger (*r*=.440, *N*=33, *p*<.02). It made no difference for this correlation (nor for the nonsignificant other ones) whether age was taken into account by means of a covariate (i.e., *r*=.437, *df=30*, *p*<.02). Age alone correlated significantly with performance in the original version (*r*=.429, *N=34*, *p*<.02), but not in the shuffled version (*r*=.098, *N*=33, n.s.). All correlations are shown in table 3.

IGT performance scores of both, children and adults, were approximately normally distributed, as confirmed by

Table 3
Correlation matrix for the children group

	Total IGT performance (combined)	Total IGT performance (original)	Total IGT performance (shuffled)	Age	Gender	KAT anxiety test
Age	.176	.429(*)	.098			
Gender	.029 *.028*	.137 *.147*	-.006 *-.006*	.010		
KAT anxiety test	.234 *.275*	-.144 *.051*	.440(*) *.437(*)*	-.182	.043 *.045*	
ZVT IQ	-.101 *-.136*	.258 *.299*	-.243 *-.295*	.174	-.113 *-.117*	-.116 *-.087*

Note. Numbers in italics reflect the correlations after controlling for age effects. All correlation coefficients are Pearson's r. Significance (2-tailed): **p* <.05.

Kolmogorov-Smirnov tests which showed only nonsignificant deviations from normal distribution. The only exception was the original version of the IGT in the children sample; but this variable did not correlate with KAT anxiety scores anyway and hence was not relevant for our hypotheses.

DISCUSSION

We have investigated the role of anxiety in decision-making in samples of children and adults using the Iowa gambling task which has been designed to test orbitofrontal function. The most interesting and novel finding of our two experiments is that various facets of anxiety seem to have a beneficial effect on gambling behaviour in the Iowa gambling task, albeit not a very strong one. This adds to previous literature which was not clear and more indirect on this point (Garon et al., 2006; Miu et al. 2008; Preston et al., 2007).

Our results show a modest but significant association between anxiety measures and total performance scores in both samples, with anxiety rendering the children perform better (i.e., more like normal adults), and anxious adults perform better than nonanxious individuals. However, in the children sample, the correlation between anxiety and performance was mostly based on the results of the shuffled version. Since Fellows and Farah (2005) showed that the shuffled version is less sensitive to OFC dysfunction, this result might indicate that anxiety has an effect on gambling performance that is independent of OFC maturation. This interpretation is further supported by our observation that the correlation between gambling performance and children age (as an indirect measure of OFC maturation) was significant only for the original version. Conversely, the correlation between gambling score and anxiety in the shuffled version remained unaffected when effects of age were controlled for. We therefore suggest that the positive effects of anxiety on gambling performance in our study may be independent of OFC functioning, contrary to our prior speculations.

In the adult sample, significant correlations with total performance scores were found for IUS (intolerance of uncertainty) and WDQ (worry domain) test scores. Furthermore, when statistically controlling for sex differences, significant correlations with performance were also found for the PSWQ (Penn state worry questionnaire) score, the ASI (anxiety sensitivity) total score and the BDI II (Beck depression inventory) score (although clinically relevant depression was an exclusion criterion). Naturally, the emotions assessed by those scales are somewhat interrelated, but we find the consistency of the associations across the range of measures and across both samples nonetheless convincing as these were independent individuals. Moreover, the consistency of the association across various levels of anxiety ranging from nonanxious over highly anxious (but still within a normal range) to clinically anxious individuals suggests that a dimensional view of pathological anxiety is appropriate – one that does not make a segregation between clinically anxious and healthy individuals but assumes the existence and graded impact of varying degrees of anxiety in-between these two poles (Endler & Kocovski, 2002; Hansell & Damour, 2008).

Intermediate forms of anxiety are referred to as 'nervousness' in the conception of Lungwitz (1955). Our main finding of anxiety as beneficial for decision-making in a prototypical gambling task is at odds with the theory of Lungwitz (1955) who stated that heightened anxiety will make individuals think and behave more 'infantilistic'. Naturally, it is not clear from his writing what areas of the neocortex he presumed to be functionally or microstructurally deficient in anxiety; hence we do not know whether his hypotheses referred to OFC mediation or other brain regions.

It is noteworthy that our scales in the adult sample measured aspects of worrying and uncertainty rather than physical anxiety symptoms. Further studies on the relationship between anxiety and decision-making should zoom in on this differentiation rather than treat anxiety as a unitary concept. In addition, preliminary studies at the University of Bochum (Germany) in patients with panic disorder have not found any differences between patients and healthy controls (Guse, 2006; Wischniewski, 2006), further suggesting that it is not so much the somatic (or 'sensile' in the Lungwitz terminology) component of anxiety that helps in decision-making, but a more cognitive component. In any case, our results show that anxiety can and does have adaptive value in situations that are commonplace in our modern society and that are mimicked by the Iowa gambling task: namely those that involve conflicting financial outcomes, and that consumers, customers, clients, traders, and investors frequently find themselves in.

In direct comparison between the two groups, we found that performance of children was similar to that of the adults. This was expected as their task was easier since it involved only fixed amounts instead of dynamically adopted payoffs. However, our adult sample was very heterogeneous in terms of age ranging from 23 to 80 years which may have additionally contributed to their relatively poor performance, given that Denburg, Tranel, and Bechara (2005) found that elderly participants tend not to shift from bad desks to good ones after some trials. Also in line with some previous results (Bolla, Eldreth, Matochik, & Cadet, 2004; Overman, 2004; Reavis & Overman, 2001) was our finding that men outperformed women in the adult group. In the sample of children, this difference was not observed. It is possible that sex hormones that come into play only during and after puberty are responsible for this gender effect.

As a final remark, we find it unlikely that intelligence has confounded our results. First, we have not found any association between the cognitive abilities tests (Connect-The-Numbers and working memory, i.e., digit span in the WISC) and gambling performance in the children sample, and second, because previous studies have found higher education to be associated with *reduced* (not enhanced) performance on the Iowa gambling task (Evans, Kemish, &Turnbull, 2004). However, some gross analyses on educational status that we performed in the adult group found no correlation between education and performance. Hence, if anything, we believe that intelligence may be detrimental to task performance. While the structure of the gambling task is rather simple, more intelligent individuals tend to wonder too much about more sophisticated (and actually non-existing) patterns behind the card sequences, and try to develop strategies that are more complex than appropriate. In contrast, what might drive individuals with high anxiety towards better performance is their specific focus on (or sensitivity to) negative outcomes, so that they avoid the high risk decks, even at the cost of lower immediate gains. It would be very interesting to investigate these individuals with the inverted variant of the gambling task (see Bechara et al., 2000) wherein relatively low immediate losses are set into conflict with potentially large rewards. Our prediction would be that anxiety does not help in this case, first because there is no big risk that needs to be avoided, and second, because anxiety does not entail a particular sensitivity towards future rewards. Notably, patients with orbitofrontal lesions are impaired on both types of the Iowa gambling task (Bechara et al., 2000), suggesting that they are generally "myopic" for events in the future rather than solely for negative events. It is an open (but empirically testable) question whether this is different in patients with anxiety disorder.

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