Title: Gambling-related brain responses in social and problem gamblers

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Background

Gambling is a common recreational activity that around 70% of the British population engage in at least annually [1], but which becomes dysfunctional in a minority. Problem gambling, where gambling has a negative impact on everyday function (e.g. debt, interpersonal conflict) has a prevalence of 1-4% [2, 3], and the more severe DSM-IV-TR diagnosis of ‘Pathological Gambling’ has a prevalence of 0.5-1.5% [4]. Within DSM, Pathological Gambling is classified as an Impulse Control Disorder, although the criteria are closely modelled on substance dependence. Problem gambling is viewed increasingly as part of an addiction syndrome [5] and has been argued to represent the prototypical ‘behavioural addiction’ [6], with potential to reveal key insights into vulnerability mechanisms and aetiological processes underlying addictions in general, in brains that are not confounded by the damaging effects of drugs [7, 8].

There is limited knowledge about the aetiological processes by which recreational gamblers become problem or pathological gamblers [9]. This transition is presumed to involve environmental, psychological and biological factors [10]. In this grant, we link neurobiological data on brain reward processing [11-13] with a cognitive approach to gambling that emphasizes how gamblers mis-perceive and over-estimate their chances of winning [14-16]. Thus, although winning outcomes during gambling are determined largely or purely by chance, the gambler develops an ‘illusion of control’ [17] such that he believes he can master the game and recoup his debts. We have developed a computerized laboratory task to elicit two of the more robust cognitive distortions associated with gambling: the near-miss effect and the effect of personal control.
Near-misses occur when an unsuccessful outcome is proximal to a win, such as when a chosen horse finishes in second place. Their significance to gamblers is widely recognised [18], to the extent that the misappropriation of slot-machine near-misses has been the focus of legal cases [19]. Studies manipulating the frequency of near-misses have shown effects on gambling persistence [20, 21], which follow an inverted-U shaped function that is maximal around 30% [21]. As a consequence of near-misses, the gambler may feel that he is ‘not constantly losing but constantly nearly winning’ [22]. These accounts of near-misses emphasise their positive, hedonic value, such that we predicted recruitment of brain reward circuitry during near-miss outcomes, despite the objective lack of monetary reinforcement on these trials.

The second factor that was examined was personal control, which refers to the gambler’s level of involvement in arranging their gamble. On games of chance like the lottery, craps and roulette, gamblers have an equal chance of winning regardless of whether they, or another agent, places the gamble. However, gamblers have inflated confidence (indicated by wager size, for example) when given the opportunity to choose their lottery ticket, or throw the dice or roulette ball themselves, compared to conditions where the action is performed by another [17, 23, 24]. The presence of personal control may be critical in causing the gambler to confuse a game of chance for a game with some controllable skill component.

The aims of the project were as follows. First, we devised a novel task, based on a simplified slot machine, to elicit near-miss and personal control phenomena in the laboratory. A behavioural version of this task, where self-report ratings were acquired on a trial-by-trial basis, was administered to 40 non-gambling undergraduates. Second, we used functional MRI to explore the brain responses during gambling play in healthy volunteers, with the aim of confirming established patterns of win-related activity and examining the brain response during cognitive distortions. We were specifically interested in a neural system comprising the ventral striatum and medial frontal cortex, which previous research has robustly implicated in processing monetary rewards.
wins [25, 26], as well as primary rewards (e.g. fruit juice) [27], social rewards (e.g. acquisition of good reputation) [28] and drugs of abuse [29, 30]. We conducted a pilot study in 10 non-gambling student volunteers, which we extended to n=16 to form a publishable dataset. Gambling propensity was measured using a clinically-oriented scale, the South Oaks Gambling Screen [31], and a measure devised for the general population, the Gambling-Related Cognitions Scale [GRCS; 32].

The third aim was to examine the brain responses during the slot machine task in a larger group of regular gamblers. We sought to extend an earlier fMRI study by Reuter et al. [33], which measured brain responses in 12 pathological gamblers and 12 controls during a card guessing task. Their analysis of monetary wins minus monetary losses indicated a blunted response in the gamblers in the ventral striatum, consistent with a reward deficiency hypothesis of gambling as a form of addiction (for similar findings in drug addictions, see [34, 35]). Their conclusion is limited, however, by the contrast baseline, as the effect in the gamblers may be driven by altered loss processing rather than blunted win processing. Thus, we sought to replicate their finding of blunted win activation in problem gamblers, using a more appropriate non-win baseline. We looked for correlations with gambling severity, and in addition, we hypothesised that problem gamblers would show greater brain activity in response to near-misses and personal control compared to social gamblers.

**Objectives**

We have taken the five objectives below directly from the original grant submission:

1) *Do problem gamblers and social gamblers differ in brain responses to monetary reinforcement?*

**Success in meeting objective: Successful.** The two fMRI studies in healthy volunteers (Expt 2 below) and regular gamblers (Expt 3 below) revealed a highly consistent brain response to monetary wins, comprising ventral striatum, insula, midbrain, and medial prefrontal cortex (Expt 2 only) (see Figure 3 and 6 below). We explored the effects of gambling severity on win activation in the regular gamblers using two approaches: a categorical comparison of problem...
(n=13) and social (n=7) gamblers, and a regression of SOGS gambling severity against brain activation. In both analyses, there was no evidence of differences in the brain response to monetary wins in problem gambling. These data fail to support the earlier findings by Reuter et al [33] and suggest their findings of blunted reward activation may be confounded by their monetary loss baseline.

2) Do near-misses activate brain reward circuitry in problem gamblers?

**Success in meeting objective: Successful.** This question became an important focus for much of the grant, as our pilot data in non-gamblers demonstrated that near-misses had robust behavioural and neural effects even in non-gamblers. The fMRI data indicated near-miss activity in the ventral striatum and insula, and the insula response correlated with the GRCS questionnaire [32] in the non-gamblers. We confirmed these same responses to near-miss outcomes in the regular gamblers (Expt 3). Thus, despite the objective lack of monetary reinforcement on near-miss trials, the brain responds to these outcomes in a manner consistent with reward delivery. We argue that this ‘anomalous’ recruitment of brain reward circuitry by near-miss outcomes underlies their ability to promote continued gambling.

3) Is the reward system sensitive to the illusion of control?

**Success in meeting objective: Successful.** In our behavioural data (Expt 1, and replicated in Expts 2 and 3), the manipulation of personal control significantly affected ratings of “chances of winning”. In Expt 1, subjects also rated monetary wins as more pleasurable if they had arranged the gamble personally. In the fMRI data, we found no corollary of these control effects on the brain response to monetary wins. However, the behavioural and neural effects of the near-misses did depend upon the presence of personal control. Specifically, subjects rated their desire to “continue to play” as higher after near-misses compared to full-misses, but only on participant-chosen trials. The interaction between the near-miss effect and personal control was also evident within part of the brain reward circuit, in the medial prefrontal cortex (specifically, rostral...
Anterior Cingulate Cortex). This finding implicates this area in the appraisal of skill during gambling.

4) Do reward-related brain activations correlate with gambling severity?

**Success in meeting objective: Successful.** In our study of regular gamblers (Expt 3 below), we saw no association between gambling severity and win-related brain activity, but a highly significant correlation between the SOGS and the brain response to near-misses in the dopaminergic midbrain. This foci suggests that excessive dopamine transmission (which is central to dominant theories of drug addiction) may underlie the invigorating effects of near-misses in gamblers.

5) Do gambling-related brain responses covary with physiological arousal?

**Success in meeting objective: Unsuccessful.** We were unable to acquire physiological arousal during functional MRI scanning. These procedures require specialized equipment, and the widely-used Biopac apparatus was not certified MRI-compatible and our scanning facility would not allow us to proceed with this aspect of the study. We have subsequently acquired psychophysiological pilot data on the slot machine task outside the scanner, and Dr Clark is seeking funding support to pursue this research.

6) Do the brain responses to reward differ across preferred forms of gambling?

**Success in meeting objective: Unsuccessful.** Whilst our group of regular gamblers comprised predominantly horse-racing and slot-machine players, cell sizes were too small to conduct meaningful comparisons between these groups that were orthogonal to the effect of gambling severity.

**Methods**

**Experiment 1**
This experiment aimed to validate the novel slot machine task in a behavioural study in 40 undergraduate volunteers (23 male). Subjects were recruited through university advertisements, and attended a single test session where they completed the slot machine task (30 minutes), the SOGS and the GRCS. The protocol was approved by the Cambridge Psychology Research Ethics Committee (♯2006.35) and volunteers provided written informed consent. Volunteers were instructed that they would have “the opportunity to win money on the task” and by virtue of the pseudo-randomised win sequence, all participants received £5 at the end of the session.

Task Design: the Slot Machine Task

The task was programmed by the PI in Microsoft Visual Basic 6, with responses registered on three adjacent keyboard keys. Trial structure and display screen are displayed in Figure 1. The task display resembles a two-reel slot machine, with the same six icons displayed on each reel, and a horizontal ‘payline’ across the centre of the screen. Subjects played 4 practice trials followed by 60 trials with monetary reward available.

Each trial consisted of 3 phases: selection, anticipation, and outcome. Selection (5s) entailed one icon on the left reel being chosen: on 30 trials (white background), the play icon was selected by the participant using two keys to scroll through the icons. On the other 30 trials (black background), the play icon was selected by the computer. During anticipation (2.8-6s), the right reel was spun and decelerated to a standstill. During outcome (4s), if the right reel stopped on the icon that was selected on the left reel (i.e. matching icons displayed in the payline), the subject was awarded £0.50; all other outcomes won nothing. Outcomes were presented in a pseudorandom order to ensure 10 wins, 20 near-misses and 30 full-misses over 60 trials. At the end of each trial, there was an inter-trial interval of variable duration (2-7s).
On each trial, subjective ratings were acquired using onscreen scales. After selection, subjects rated “How do you rate your chances of winning?” and after outcome, two further ratings were taken: “How pleased are you with the result?” and “How much do you want to continue to play the game?”.

Experiment 2

This experiment assessed brain responses to the slot machine task in 16 healthy volunteers. One subject was excluded from analysis due to excessive movement (~4mm within session, with pronounced spiking), leaving 15 subjects (9 male, mean age 26 s.d 7.5) in the reported analysis. Subjects reported zero or mild involvement in gambling, indexed by scores on the SOGS of 0-3 (see Table 2). Subjects attended a single fMRI session at the Wolfson Brain Imaging Centre in Cambridge, U.K.. The protocol was approved by the Norfolk & Norwich Research Ethics Committee (COREC 06/Q0101/69) and all volunteers provided written informed consent. Volunteers were reimbursed £20 for participation “with the opportunity to win further money on the task” (£15 over 180 trials).

The task was modified slightly for fMRI: 1) the auditory feedback was removed given the noise of the scanner, 2) more trials were acquired (3 blocks of 60 trials) to enable sufficient power for fMRI analysis, and 3) the number of ratings was reduced given the longer task duration: the ‘pleased with outcome’ rating was dropped altogether, and the ratings of ‘chances of winning’ and ‘continue to play’ were acquired, at random, on 1 in 3 trials. Responses were recorded using the first 3 buttons on a 4-button box, resting on the subject’s stomach under the dominant hand. Subjects performed 10 practice trials on the task (delivering two hypothetical wins) before entering the fMRI scanner.

Imaging Procedure. Scanning was performed on a 3 Tesla magnet using a standard acquisition protocol (see Clark et al, in press and nominated output for full fMRI methods). Subjects
performed three 60-trial blocks of task, each lasting 630 repetitions (21 mins), but with blocks typically terminated early on block completion. Analysis was performed using SPM5 (Statistical Parametric Mapping, Wellcome Department of Cognitive Neurology, London, UK). Data preprocessing consisted of slice timing correction, within-subject realignment, spatial normalization using a segmented MP-RAGE structural scan also acquired on the scan session, and spatial smoothing using a 10mm Gaussian kernel. Time series were high pass filtered (128s). Volumes were normalised to the International Consortium for Brain Mapping (ICBM) templates that approximate to Talairach & Tournoux [36] space. A canonical hemodynamic response function (HRF) was modelled to the outcome phase on each trial, with the onsets for selection and anticipation also included in the design matrix. At outcome, eight trial types were distinguished, comprising a 2 (choice: participant-chosen, computer-chosen) by 4 (win, near-miss before the payline, near-miss past the payline, full-miss) factorial design. In this report, we focus on three contrasts: 1) Win-related activity (all wins minus all non-win outcomes on participant- and computer-chosen trials), 2) Near-miss activity: all near-misses minus all full-misses, on participant- and computer-chosen trials, 3) Near-miss by choice interaction: areas differentially recruited by near-misses compared to full-misses as a factor of participant vs computer control (i.e. 1, -1, -1, 1). Contrasts 2 and 3 were restricted to areas showing win-related activity (i.e. masked with contrast 1), and based on the behavioural data in Experiment 1, contrasts 2 and 3 were repeated restricted to near-miss outcomes where the play icon passed through the payline. Individual contrast images were taken to a second-level random-effects group analysis, and were thresholded at p<.05 corrected for multiple comparisons using the Family Wise Error (FWE) correction [37].

Experiment 3

Thirty-three regular gamblers (3 female) were recruited via community and internet advertising. All subjects completed a screening session that included a clinical interview, and a second session that involved a functional MRI scan. The protocol was approved by the Norfolk & Norwich Research Ethics Committee (COREC 06/Q0101/69) and all volunteers provided written
informed consent. In total, good quality fMRI data were available on 20 subjects. The 13 exclusions were due to exclusion on the day of scanning (history of head injury, excessive body-weight) (n=2), withdrawal during scanning due to claustrophobia (n=3), excessive movement during scanning (defined as >5mm within a run) (n=4) and a failure to report to the fMRI facility on the day (n=4). The final sample (18 male, 2 female) had a mean age of 33.7 (sd 1.8) and 14.5 (sd 0.5) years in education. Consistent with the clinical phenomenology of problem gambling [4, 38], our sample displayed moderate clinical comorbidity with lifetime anxiety disorders (n=3), mood disorders (n=7) and drug/ alcohol abuse (n=11). Urine samples revealed 5 positive results (4 cannabis, 1 benzodiazepines). Four further subjects were taking prescription medications. Gambling severity was measured using the SOGS and the GRCS. The task and imaging procedure were unchanged from Experiment 2. Volunteers were reimbursed £40 for the two sessions, and won an additional £15 on the task. Having established the neural circuitry linked to the task in Experiment 2, we implemented a more liberal statistical threshold of p<.001 uncorrected for multiple comparisons for our imaging analyses.

Results

In Experiment 1, the self-report ratings on each trial were z transformed to each subject’s individual mean and standard deviation for statistical analysis. The ratings of “How do you rate your chances of winning?” taken after selection showed a significant effect of personal control, with higher ratings on participant-chosen trials compared to trials where the computer selected the play icon (t39=5.09, p<.001) (see Figure 2). The personal control manipulation also affected the hedonic response to winning outcomes: ratings of “How pleased are you with the result?” were significantly higher on participant-chosen wins compared to computer-chosen wins (t39=2.50, p=.017) (see Table 1).

Table 1: Subjective ratings (raw score, and Z-standardised score based on the mean and standard deviation for that subject) on the Slot Machine Task (Experiment 1; n=40)

<table>
<thead>
<tr>
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<th>Participant-Chosen</th>
<th>Computer-Chosen</th>
</tr>
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<tbody>
<tr>
<td>“How do you rate your chances of winning?” (0=very low, 100=very high)</td>
<td>Raw 35.1 (14.8)</td>
<td>29.9 (12.7)</td>
</tr>
<tr>
<td></td>
<td>Z 0.16 (0.20)</td>
<td>-0.16 (0.20)</td>
</tr>
</tbody>
</table>

“How pleased are you with the result?” (-100=very unhappy, 0=neutral, +100=very happy)
The subjective response to the near-miss outcomes was striking: near-misses were experienced as aversive according to the ratings of 'pleased with result', but simultaneously increased ratings of “How much do you want to continue to play the game?”. Both effects varied as a function of personal control ('pleased with result’ control x outcome interaction $F_{2,78}=12.3$, $p=.001$; ‘continue to play’ control x outcome interaction $F_{2,78}=6.50$, $p=.002$). Compared to computer-chosen near-misses, participant-chosen near-misses were significantly less pleasant ($t_{39}=-4.21$, $p<.001$) but significantly more motivating ($t_{39}=4.69$, $p<.001$). Compared to participant-chosen full-misses, participant-chosen near-misses were significantly less pleasant ($t_{39}=-2.75$, $p=.009$) and significantly more motivating ($t_{39}=2.66$, $p=.011$) (see Figure 2). Further post hoc analysis revealed that the effect of the near-misses to increase ratings of ‘continue to play’ on participant-chosen trials was predominantly driven by trials where, during reel spinning, the play icon moved through the payline and stopped in the next position (mean $z=+0.18$), compared to near-misses where the chosen icon stopped one position short of the payline (mean $z=-0.19$) ($t_{39}=3.90$, $p<.001$).

Figure 2: A) The manipulation of personal control (participant-chosen versus computer-chosen trials) affected ratings of “How do you rate your chances of winning?”. B) Compared to full-miss outcomes, near-misses increased...
ratings of “How much do you want to continue to play?” on trials where there was personal control.

In Experiment 2, we looked at the neural correlates of the slot machine task using fMRI in a second group of 15 healthy volunteers. The contrast of wins against non-wins yielded significant signal change (thresholded at $p<.05$ FWE) in a distributed circuit comprising the ventral striatum, the anterior insula, the rostral anterior cingulate cortex (rACC), the thalamus and the dopaminergic midbrain (see Figure 3A). This circuit is reliably activated in previous imaging studies using both unconditioned and conditioned reinforcers [25-27, 39-41].
The contrast comparing the near-miss outcomes against the full-miss outcomes showed a response to near-misses in the ventral striatum ($x, y, z = -8, 4, -2, Z = 4.30, p_{FWE-corr} = .005$; $12, 2, 2, Z = 4.25, p_{FWE-corr} = .006$) and the right anterior insula ($x, y, z = 32, 18, 0, Z = 3.63, p_{FWE-corr} = .049$), despite the lack of objective monetary gain on those trials (see Figure 3B). These responses were present on trials with, and without, personal control. A third contrast assessed the interaction of the near-miss effect (near-misses minus full-misses) and personal control (participant-chosen trials minus computer-chosen trials), and identified bilateral voxels in the rACC region, at a level of significance just below our FWE threshold ($x, y, z = 4, 32, 2, Z = 3.48, p_{FWE-corr} = .062$; $x, y, z = -4, 38, 2, Z = 3.36, p_{FWE-corr} = .088$). When this contrast was confined to near-misses that had passed through the payline and stopped in the next position, these voxels were fully significant despite the restricted number of events ($x, y, z = -4, 38, 2, Z = 4.34, p_{FWE-corr} = .005$; $x, y, z = 4, 34, 2, Z = 3.97, p_{FWE-corr} = .019$; $x, y, z = 6, 38, 2, Z = 3.67, p_{FWE-corr} = .049$). An analysis of extracted signal change from these voxels showed greater activity on near-misses compared to full-misses on
participant-chosen trials ($t_{14}=3.37, p=.005$), with a marginally significant effect in the opposite direction on computer-chosen trials ($t_{14}=-2.06, p=.058$) (see Figure 4).

Figure 4: The interaction between personal control and the near-miss effect in the rostral Anterior Cingulate Cortex.

Neural responses to wins and near-misses were regressed against two sets of variables. First, we looked for brain areas where neural responses were correlated with the GRCS. When GRCS score was regressed onto near-miss activity, there was a significant cluster in the anterior insula ($x, y, z=-42, 18, -10; Z=3.98, p_{FWE-corr}=.018$) (see Figure 5A). This correlation indicates that subjects who rated themselves as more susceptible to gambling distortions showed greater recruitment of the anterior insula in response to near-miss outcomes. Second, we looked for brain areas where neural responses to wins and near-misses were correlated with the subjective ratings of ‘continue to play’. When the subjective near-miss effect was regressed against near-miss related brain activity, adjacent voxels in the anterior insula and orbitofrontal cortex were the only significant effects at a reduced threshold of $p<.001$ uncorrected for multiple comparisons ($x, y, z=30, 16, -10; Z=3.24, p_{unc}=.001; x, y, z=34, 24, -4, Z=3.37, p_{unc}<.0001$). This correlation indicates that subjects who reported greater subjective effects of the near-misses on their ratings of ‘continue to play’ showed a greater brain response to near-miss outcomes in the anterior insula and adjacent orbitofrontal cortex (see Figure 5B).

Figure 5: The fMRI response to near-miss outcomes in the anterior insula was positively correlated with A) a trait index of gambling propensity that is significantly elevated in problem gamblers, and B) the subjective impact of those events on ratings of ‘continue to play’ the task.
In Experiment 3, the brain responses during the slot machine task were assessed in 20 regular gamblers.

The contrast of winning outcomes against all non-win outcomes showed significant areas of activation in the ventral striatum, thalamus, insula and the dopaminergic midbrain (thresholded at $p<.001$ uncorrected) (see Figure 6A); areas that overlap with the win-related circuitry in non-gamblers in Experiment 2. We then contrasted the response on near-miss outcomes against the response on full-miss events, in brain regions that were activated in the (orthogonal) win minus non-win contrast. Also confirming our effects in Experiment 2, near-misses in the regular gamblers activated left ventral striatum ($x, y, z=-16, 0, -8, z=3.22, P_{unc}=.001$), right ventral striatum ($x, y, z=18, 6, -2, z=3.67, P_{unc}<.001$) and right insula ($x, y, z=28, 22, -10, z=3.20, P_{unc}=.001$), with an additional response in the thalamus ($x, y, z=-4, -12, 4, z=3.12, P_{unc}=.001$) (see Figure 6B).

Figure 6: A) Brain responses to monetary wins (minus all non-win outcomes) in regular gamblers in Experiment 3. B) Brain responses to near-miss outcomes (minus full-miss outcomes) in regular gamblers.
Brain responses during gambling were related to individual differences in gambling severity using two approaches. First, the group of 20 were divided into two subgroups, of 7 ‘social’ gamblers (SOGS<5) and 13 probable Pathological Gamblers (SOGS≥5). Independent-samples t tests revealed no significant differences between these two subgroups in patterns of win-related or near-miss related brain activity. However, SOGS scores indicated a continuous distribution of gambling involvement/severity (see Figure 7). Thus, as a second, data-driven approach, we regressed gambling severity onto the fMRI brain responses. In the regression of SOGS against win-related brain activity, we saw no significant brain voxels. Thus, our data fail to support the findings reported by Reuter et al [33] that pathological gamblers show blunted ventral striatal activity to monetary wins in comparison with monetary losses. However, we also predicted that gambling severity would be associated with relatively stronger brain responses to near-miss outcomes, as an expression of the cognitive distortions in problem gambling. Consistent with this hypothesis, we observed a significant positive correlation between SOGS score and near-miss related brain activity in the midbrain (x, y, z=-8, -18, -16, z=5.30, P_{unc}<.001) and globus pallidus (x, y, z=12, -4, -8, Z=4.09, P_{unc}<.001). Based on this finding and the observed GRCS correlations in Experiment 2, we also regressed near-miss related brain activity onto the GRCS subscales (see
Table 2). Near-miss related brain activity in the dopaminergic midbrain was highly and selectively associated with the GRCS Inability to Stop subscale (sample item: “I’m not strong enough to stop gambling”) \((x, y, z=-8, -20, -16, Z=3.80, P_{unc}<.001)\) (see Figure 8). Given the small volume of these brainstem nuclei, we have re-smoothed our data using a smaller (4mm) smoothing kernel, and have confirmed that midbrain response to near-misses is proximal to the substantia nigra.

Figure 7: Distribution of scores on the South Oaks Gambling Screen in 20 community-recruited regular gamblers in Experiment 3.

Figure 8: Correlation between gambling severity (GRCS Inability to Stop subscale) and the response to near-miss outcomes (minus full-miss outcomes) in the midbrain.

Table 2: Scores on the South Oaks Gambling Screen and Gambling-Related Cognitions Scale in the three studies
<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>40</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>SOGS</td>
<td>0.9 (1.13) (range 0-5)</td>
<td>0.67 (0.98) (range 0-3)</td>
<td>7.25 (1.28) (range 0-19)</td>
</tr>
<tr>
<td>GRCS-Total</td>
<td>51.0 (19.6)</td>
<td>42.6 (15.8)</td>
<td>71.0 (19.2)</td>
</tr>
<tr>
<td>GRCS Subscales:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gambling Expectancies</td>
<td>9.48 (3.49)</td>
<td>7.67 (4.02)</td>
<td>14.9 (4.27)</td>
</tr>
<tr>
<td>Illusion of Control</td>
<td>7.95 (5.02)</td>
<td>6.87 (3.31)</td>
<td>7.15 (3.70)</td>
</tr>
<tr>
<td>Predictive Control</td>
<td>14.9 (7.00)</td>
<td>12.5 (4.30)</td>
<td>20.9 (8.04)</td>
</tr>
<tr>
<td>Inability to Stop</td>
<td>6.6 (4.98)</td>
<td>5.87 (2.59)</td>
<td>11.2 (7.11)</td>
</tr>
<tr>
<td>Interpretive Bias</td>
<td>12.1 (5.65)</td>
<td>9.73 (5.56)</td>
<td>16.9 (3.93)</td>
</tr>
</tbody>
</table>

Activities

The PI has attended two meetings of the Responsibility in Gambling Trust over the course of the grant, which have enabled communication between the award-holders, representatives from government (e.g. the Gambling Commission), research councils and gambling industry. The Gambling and Social Responsibility Forum (Manchester, September 2008) achieved similar aims.

The PI has established links within economics, presenting preliminary data at a workshop entitled ‘Rationality and Emotion’ in January 2008 (involving D Prelec, A Kirman, A Rustichini, J Coates) which has led to an accepted proposal for a special issue of Philosophical Transactions of the Royal Society. The PI has had a symposium proposal accepted for the British Association of Psychopharmacology summer meeting in July 2009, entitled ‘Psychopharmacology of Decision-Making: from Brain Mechanisms to Gambling Addiction’, with other talks by Dr RD Rogers (also funded under the ESRC-RiGT initiative) and Dr Marc Potenza (Yale University). The PI has a further symposium application under review for the Society of Biological Psychiatry annual meeting (May 2009), and has other scheduled presentations to present this research at the College for Problems in Drug Dependence (San Diego, June 2009) and the International Society for Research in Impulsivity (Reno, Nevada, June 2009).

Outputs

We are in the process of depositing final spreadsheets at the ESDS. The grant has generated one publication that has been recently accepted at the prestigious journal *Neuron* (2007 ISI impact
factor 15.9), with an expected date of publication in early 2009. We will arrange a press release to coincide with its publication through the University Communications Office:


A second paper reporting the brain responses in the regular gamblers (Experiment 3 above) is in preparation and we expect to submit in January 2009:


A third review article has arisen from the Rationality and Emotion workshop and is in preparation for a special issue of *Philosophical Transactions of the Royal Society* (part B), with a deadline of January 2009:


In addition, the following media articles have been released over the course of the grant:

Nature Neuropod podcast on risky decision-making, April 2008.


Radio interview on Gambling behaviour, BBC Radio Cambridgeshire (Drivetime), 14th February 2008.


The psychology of gambling, University of Cambridge ‘Research Horizons’ magazine, Summer 2007.

**How to hit the jackpot: just play it 15m times. Sunday Times, 28th January 2007.**

The psychology of near misses. BBC News Online, 25th May 2006.

Impacts

The research is not likely to yield any directions for commercial exploitation. Stakeholders including the research councils and gambling industry representatives will be informed of the findings through media dissemination and at a one-day meeting to be organized by the Responsibility in Gambling Trust.

Future Research Priorities

The PI has recently submitted an MRC grant application with Dr Henrietta Bowden-Jones, to look at psychological function in treatment-seeking Pathological Gamblers attending the first NHS clinic for gambling, which is run by Dr Bowden-Jones. If funded, this project will constitute the first large-scale attempt to characterize the clinical and neurocognitive profiles of severe problem gamblers in the UK. The application, if successful, will lead to future funding bids to quantify dopamine function in problem gamblers, using PET radioligand imaging. This will extend our observed association between gambling severity and increased dopaminergic midbrain response in regular gamblers. The MRC application involves collaboration with two other centres of excellence, in Oxford (Dr RD Rogers) and Amsterdam (Dr A Goudriaan). The PI has also submitted a second grant to the Royal Society to investigate the physiological correlates of the near-miss effect in non-gambling students. We hypothesise that participant-chosen near-misses will be associated with increases in heart rate and skin conductance, similar to the responses to winning outcomes. We also predict that these psychophysiological responses will covary with susceptibility to gambling biases, measured with the GRCS.

References