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A Cognitive Neuroscience Approach to Studying the Role of Overconfidence in Problem Gambling

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Abstract Research on the neural correlates of decision making in gambling tasks may be informative for understanding problem gambling. The present study explored confidence and overconfidence using magnetoencephalography (MEG) to measure brain activity during a judgment task. Nineteen undergraduates who self-identified as frequent gamblers (average age 19.7 years; 5 females, 14 males) participated in this study. Participants first completed the DIGS (Winters, Specker & Stinchfield, 2002), a measure of gambling pathology. They then engaged in a behavioral task of confidence assessment, wherein they answered two-alternative trivia questions and estimated the probability that each answer was correct. In a subsequent MEG task, they viewed the questions and a target answer, and indicated with a button press whether the target matched the correct answer. Confidence was directly related to activity in the right prefrontal cortex. Matching and mismatching targets were associated with activity in the medial occipital cortex and left supramarginal gyrus, respectively. An interaction of pathology and match/mismatch was observed in the right inferior occipital-temporal junction region, showing more activity following a mismatch in non-problem gamblers, but not in problem gamblers. Implications of the results for understanding of top–down modulation and attentional systems are discussed in relation to gambling behavior.

Keywords Cognitive neuroscience · Decision making · Overconfidence · Gambling · MEG

Introduction

A body of research on gambling behavior in general, and problem gambling in particular, has focused on the role that cognitive distortions play in gambling behavior or its associated pathology (Petry, 2005a, b). For example, Baboushkin,

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Hardoon, and Derevensky (2001) identified a list of cognitive illusions that occurred more frequently among probable pathological gamblers than among social gamblers in a university student population. Steenbergh, Meyers, May, and Whelan (2002) developed and validated an extensive questionnaire of gamblers' beliefs, based on a broad-ranging survey of errors and biases from basic cognitive psychology literature. They reported two primary factors that contributed to problem gambling: the illusion of control, and a belief that luck, perseverance or both will eventually lead to winning bets. The illusion of control was first described by Langer (1975), and can be defined as an exaggerated belief in one's ability to determine the outcome of an uncertain event. This concept has attracted considerable attention in gambling research. For example, Davis, Sundahl, and Lesbo (2000) found that participants bet more and accepted more difficult bets when betting on their own dice rolls than when betting on another person's dice rolls. Some researchers (Dixon, 2000; Kweitel & Allen, 1998; Moore & Ohtsuka, 1999) have explored the possibility of altering perceived control as a means for treating pathological gambling.

A number of clinical treatments based on correcting cognitive distortions have been developed (e.g., Ladouceur et al., 2001; Ladouceur, Walker, & Becona, 1998; Petry, 2005a, b; Robson, Edwards, Smith, & Colman, 2002; Toneatto, 1999; Toneatto, 2002), as has at least one prevention program (Ferland, Ladouceur, & Vitaro, 2002). These and other efforts at both basic and clinical levels, many of which have had notable degrees of success, have led some observers to conclude that cognitive-based approaches to treating and preventing gambling-related problems carry special promise (e.g., Ladouceur, Sylvain, Boutin, & Doucet, 2003; Toneatto & Ladouceur, 2003; Toneatto & Millar, 2004).

Gambling neuroscience

In addition to developing effective treatments for pathological gambling based on cognitive approaches, some researchers have been interested in identifying the neurobiological correlates of gambling behavior and gambling problems. For instance, when shown gambling cues, pathological gamblers show increased activity in the right prefrontal cortex (Crockford, Goodyear, Edwards, Quickfall, & el-Guebaly, 2005). They also show deficits in risky decision making tasks that are similar to those observed among patients with lesions of the ventromedial prefrontal cortex (Cavedini, Riboldi, Keller, D'Annucci, & Bellodi, 2002), and perform on a risk attitude task similar to that observed among patients with damage to dorsolateral prefrontal and orbitofrontal cortices (Brand et al., 2005).

An important step in a cognitive neuroscience approach to studying gambling behavior, including gambling-related problems, is elucidation of fundamental cognitive processes that underlie the false beliefs that are associated with gambling. Delfabbro (2004) lamented the "stubborn logic of regular gamblers," that false beliefs about luck, control and probability are not eradicated by simply informing gamblers of relevant facts. The false beliefs frequently persist because the cognitive processes that gave rise to the false beliefs, which are more basic than the false beliefs themselves, have not been altered. Goodie (2005) measured basic aspects of risky decision making among problem and non-problem gamblers, using the Georgia Gambling Task (Goodie, 2003), which combines overconfidence (an unrealistically optimistic belief about the probability of a favorable outcome) with risk attitude in determining the number of points that are earned in a test of participants' knowledge or other skill. Goodie (2005) found that problem and pathological gamblers were consistently more overconfident than non-problem gamblers; were more risk seeking under some condition; and, when the element of control was removed, problem gamblers, compared with non-problem gamblers, abated their risk-taking significantly less.

Some research has investigated the neural correlates of risky decision-making. Schutter and Van Honk (2005) recently reported spontaneous EEG correlates of sensitivity to the reward and punishment aspects of the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994). Participants with more low-frequency brain activity (typically reported among persons with non-specific brain damage) had less advantageous decision making strategies than those with relatively more high frequency brain activity. More specifically, Tranel, Bechara, and Denburg (2002) reported that poor decision-making and profound disturbances of social and interpersonal functioning were specifically associated with damage to the right frontal cortex. It also has been found that confidence is associated with activation of right dorsolateral prefrontal cortex (Henson, Rugg, Shallice, & Dolan, 2000).

In the present report, we explore the neural correlates of basic cognitive effects that Goodie (2005) found to be differentially associated with problem gambling: confidence and overconfidence. We had two goals: (1) to describe the neural correlates of confidence across participants, as research in this area is rare; and (2) to study differences in neural activation associated with confidence judgments between problem and non-problem gamblers. To accomplish these goals, we used whole head magnetoencephalography (MEG), a functional neuroimaging tool that yields direct measurement of neural activity with temporal resolution in the millisecond range (Wang & Kaufman, 2003).

Methods

Participants

Nineteen University of Georgia undergraduate students (Age $M = 19.72$ years, $SD = 1.07$; 5 females and 14 males) participated in this study. In order to obtain a robust sub-sample that showed signs of problem gambling, the recruiting notice sought only participants who self-identified as gambling at least weekly. This recruiting strategy has worked successfully in the past (Goodie, 2005). All participants were right-handed, free of serious physical health problems, absent of known neurological disorders, and free of substance use disorder within the last 6 months (all by self report). Participants were also screened for contraindications for MEG recording (e.g. metal in their body, extensive dental work). This research project was approved by the University of Georgia Institutional Review Board, and all participants provided informed consent. Participants received credit towards class requirements.

Stimuli and procedure

Participants were administered the Diagnostic Interview for Gambling Severity (DIGS; Winters, Specker & Stinchfield, 2002) to establish their degree of gambling-related pathology. The median DIGS score was 3, which provided a convenient median-split because of the frequent distinction in the literature between ''non-problem gamblers'' (those who show 0–2 DSM-IV criteria) and subclinical ''problem gamblers'' (those who show 3–4 criteria). The sample included five participants with DIGS scores of 5 or higher, indicating pathological gambling.

The remainder of the study included a behavioral session and an MEG session. The behavioral session consisted of a confidence calibration task that consisted of a series of U.S. state pairs, which were initially selected at random and then presented in the same order to all participants. Participants sat in front of a data collection computer, running software developed in the Delphi™ environment, and were presented successively with 180 pairs of states to be compared on the dimension of population (Fig. 1A). Participants clicked with a mouse on the state that they thought had the larger population, and then assessed their confidence in their answer being correct, by clicking the mouse on one of seven confidence intervals: 50–52%, 53–60%, 61–70%, 71–80%, 80–89%, 90–97% or 98–100%. These methods have been used successfully in this laboratory (Campbell, Goodie, & Foster, 2004; Goodie, 2003, 2005; Schaefer, Williams, Goodie, & Campbell, 2004).

Upon completing the confidence assessment phase, participants were taken to the MEG laboratory for evaluation of neural activity during performance of a similar judgment task. After being familiarized with the environment and MEG equipment, participants were given instructions for the task (Fig. 1B). In each trial, they were required to fixate on a cross at the center of the screen (1,500 ms). While the fixation

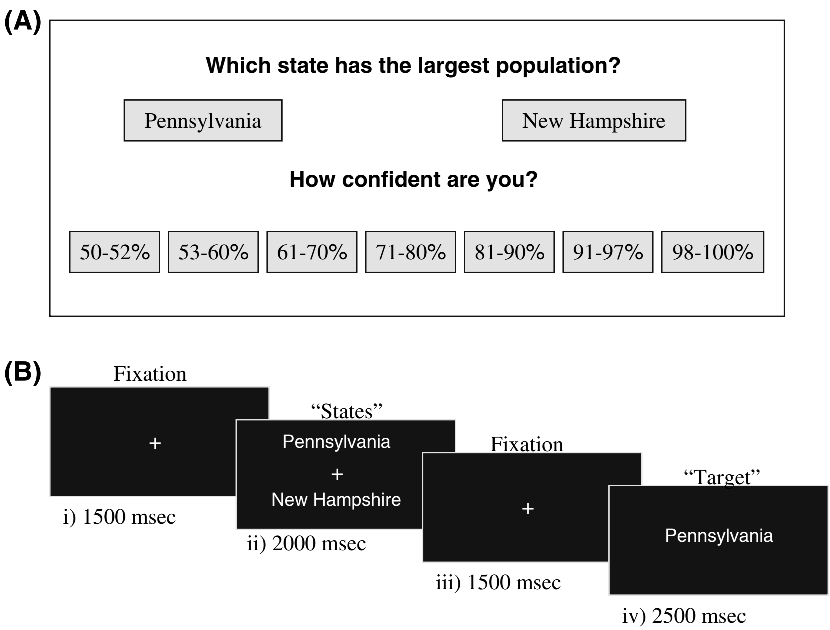

Fig. 1 (**A**) Sample trial used during confidence assessment session. Participants first decided which of two U.S. states had a larger population, and then assessed the confidence of their decision. (**B**) Sample trial used during MEG session: (i) a centrally presented fixation cross for 1,500 ms; (ii) participants maintained fixation on cross while the pair of states was presented for 2,000 ms; (iii) participants maintained fixation on the cross for 1,500 ms; (iv) participants had 2,500 ms to press one of two buttons corresponding to whether the presented target was correct or incorrect

cross stayed on, two states appeared, one above and one below the cross (2,000 ms). Participants were required to maintain fixation while they decided which state had the larger population (1500 ms). Then, the central fixation cross was replaced with one of the two states, selected randomly (2,500 ms). Participants were to press one of two buttons (left or right, counterbalanced across subjects) depending on whether they thought the given answer was a ‘‘match’’ or a ‘‘mismatch’’ to the correct answer. The MEG run consisted of 180 trials (the same series and order as in the confidence assessment session) displayed by Presentation software (Neurobehavioral Systems, Inc, Albany, CA). Stimuli were projected on a screen that was 35 cm in front of the participant. A break was provided after 90 trials.

MEG data acquisition

Three head localization coils (positioned at the nasion, and left and right preauricular points) and Ag–AgCl electrodes (positioned at the outer canthi of each eye, and above and below the left eye for recording of horizontal and vertical eye movements, respectively) were affixed prior to testing. MEG recordings were obtained using a 143 channel CTF OMEGA whole head system (CTF/VSMMedtech Ltd., Coquitlam, BC, Canada). MEG data were recorded continuously, sampled at 600 Hz, with an analog filter bandpass of 0.6–300 Hz. Head shape was digitized using a Polhemus Fastrak (Polhemus Inc., Colchester, VT, USA) for later co-registration of head position relative to MEG sensor locations.

MEG sensors do not move with the head during recording, so it is necessary to promote and monitor head stabilization throughout testing. An inflatable air bladder was fitted to the subject’s head (like a stocking cap) to discourage movement. Additionally, head position relative to sensor locations was measured at the beginning and end of testing. For this standard procedure, small currents were introduced through the coils affixed to the fiducial locations. The locations of these coils were determined by fitting single equivalent current dipoles to the generated magnetic fields. This procedure allowed confirmation that participants’ heads were in a fixed position relative to the sensors throughout testing. For a partcipant’s data to be used, the coil positions over time could not differ by more than 3 mm in any plane.

MEG data analysis

Raw MEG data were visually inspected offline for bad channels, and bad channels were eliminated prior to source analyses (no participant had more than four bad channels). The remaining MEG data were screened and segmented around stimulus triggers using BESA 5.0 (MEGIS Software GmbH, Gräfelfing, Germany). Blinks were corrected using the spatial filtering algorithm of Berg and Scherg (1994). Data were visually inspected for other artifacts (e.g., rolling lateral eye movements, muscle artifacts, any unspecified activity greater than 2.5 pT in amplitude), and trials containing these events were eliminated from averaging. Data were digitally bandpass filtered from 2 to 30 Hz.

Each trial was tagged for the level of confidence reported in the confidence assessment phase. Due to small number of trials available at some confidence levels, individual trials were collapsed across levels into high confidence (80–100%) or low confidence (50–79%). High and low confidence trials were averaged separately. For each participant, data were then averaged within the following conditions (see Fig. 1): (1) ‘‘States’’, the period during all trials when the two states were presented together; (2) ‘‘Target—matched’’, when the target was presented and matched the correct answer; (3) ‘‘Target—mismatched’’, when the target was presented and did not match the correct answer. Only trials in which participants answered correctly were included in these analyses. Averaged responses were then constructed using all available trials from 100 ms before to 450 ms after onset of each stimulus (‘‘states’’ or ‘‘target’’).

Locations of sources in the brain cannot be directly observed with MEG, and activity at an individual sensor does not clarify from what region of the brain that activity emanated (Picton et al., 2000). Algorithms are available, however, that allow for neural sources to be inferred from the distribution of MEG signals recorded from multiple sensors. Indeed, by imposing reasonable constraints, unique solutions for the ‘‘bioelectric inverse problem’’ can be calculated (Wang & Kaufman, 2003). Source analyses in the present manuscript used the minimum norm estimate approach to solving this computational problem (Wang & Kaufman, 2003). For the minimum norm estimate approach, the source configuration is fixed *a priori* (fixed source locations are specified on the surface from which the MEG signals emanated; e.g., the cerebral cortex). The minimum norm solutions here were calculated using BESA 5.0 and the method of Dale and Sereno (1993) using a spherical shell to model the brain case (with the diameter of the shell equal to 80% of the distance between the left and right pre-auricular points for each subject) on which were located 162 evenly spaced sources (the standard configuration in BESA 5.0). Given the measured data, estimates of dipolar strength were calculated for each source at each time point, with errors minimized in a least-squares sense. The final solution is the one having the lowest energy (thus, ‘‘minimum norm’’).

The average activity at each source location was calculated over 50 ms time intervals separately for the six conditions described above (states, match and mismatch for high and low confidence). Seven 50 ms time periods beginning at 50 ms after stimulus presentation and ending 450 ms after stimulus presentation were analyzed. Many participants began making button-press responses after 450 ms, and so subsequent time points were not analyzed. Statistical analyses were performed for each source location on each time interval using scripts written in Matlab (Mathworks, Natick, MA). First, for the ‘‘states’’ presentation, a dependent-measures *t*-test was conducted to test for differences between means on state pairs which participants reported high (M = 73.6 trials, SD = 33.6) versus low (M = 69.1 trials; SD = 37.1) confidence. For the ‘‘matched’’ and ‘‘mismatched’’ presentations, a repeated-measures ANOVA was conducted to test for effects of type of answer (matched or mismatched) and confidence (high or low). For matched trials, there were 34.7 (SD = 14.3) available high confidence and 22.5 (SD = 13.2) low confidence trials. For mismatched trials, there were 29.3 (SD = 14.1) high confidence and 21.6 (SD = 14.0) low confidence trials. These calculations were performed individually for all 162 sources.

Traditional Bonferroni correction for multiple comparisons leads to prohibitively low alpha levels that would reduce the ability to detect real brain activations in functional neuroimaging studies. Thus a technique that is often used in the fMRI literature (Dimitriadou, Barth, Windischberger, Hornik, & Moser, 2004; Forman et al., 1995), which integrates the probability of significance for a single source with the probability of significance for a cluster of sources, was adapted for use in the present study (see Gilmore, Clementz, & Buckley, 2005, for an example with dense array EEG data). This type of cluster thresholding was done because source analyses with MEG data result in significant activations of multiple sources in close proximity to one another. Based on Monte Carlo simulations calculated using ALPHASIM in AFNI (Cox, 1996), the following rules for statistical significance were determined to maintain a familywise alpha level of no greater than .05: (1) an individual test at a single source was significant at $P < .035$, and (2) at least two other neighboring sources were also significant at $P < .035$. Maps of significant differences between the groups were then projected onto the cortical surface of an averaged brain.

Simple effects were then evaluated within those areas that showed significant differences (see Fig. 2). For clusters of source locations in which there was a significant main effect of confidence or match/mismatch, minimum norm activity was averaged over those locations, separately for each condition. Simple effects between low/high confidence or match/mismatch were evaluated using pairwise *t*-tests. Likewise, for clusters of source locations in which there was a significant interaction between gambling and match/mismatch effects, minimum norm activity was averaged across those locations, separately for non-problem gamblers, problem gamblers, match and mismatch conditions. Simple main effects were then evaluated with a 2×2 mixed model ANOVA (Fig. 2).

Results

MEG results

Confidence effects

There was a significant main effect of confidence on brain activity from 50 to 100 ms after presentation of the target answer in a right prefrontal cortex (PFC) region. Brain activity was significantly increased during high compared to low confidence responses ($t(1,18) = 3.23$, $P < 0.05$; see Figs. 2A, 3A). There were no other significant main effects of confidence on brain activity.

Match/mismatch effects

Results showed significant main effects of type of target answer on brain activity. First, there was greater activity in medial occipital cortex from 50 to 100 ms after stimulus presentation when participants were presented with the correct (“match”) compared to the incorrect (“mismatch”) answer ($t(1.18) = 3.38$, $P < 0.05$; see Figs. 2B, 3B). Second, there was greater activity in the left supramarginal gyrus region from 150 to 200 ms after stimulus presentation when participants were presented with the mismatched compared to the matched answer, ($t(1,18) = 3.60$, $P < 0.05$; see Figs. 2C, 3B).

Gambling effects

There was an interaction between gambling pathology and type of answer on brain activity, which persisted across time. A consistent effect was observed in the right

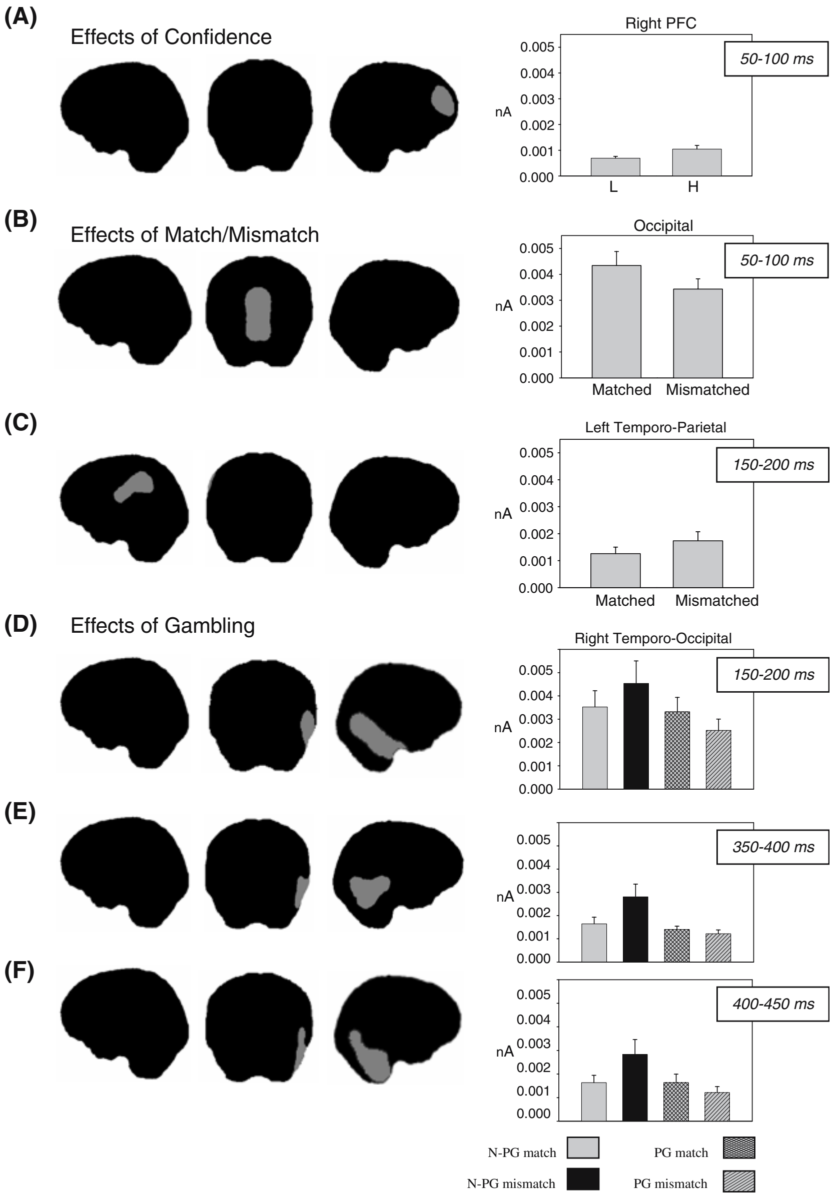

Fig. 2 ANOVA results showing significant differences of neural activity. *F* test results maps are projected onto the cortical surface of an averaged MRI (left, back and right views, respectively). Gray represents significant main effects of confidence (**A**), main effects of match/mismatch (**B**, **C**), and significant interactions between gambling tendencies (PG and N-PG) by type of answer (matched and mismatched; **D**–**F**). Bar graphs depict minimum norm activity averaged over source locations within the area that showed significant effects (means and standard error bars are shown). LC, low confidence; HC, high confidence; N-PG, non-problem gamblers; PG, problem gamblers

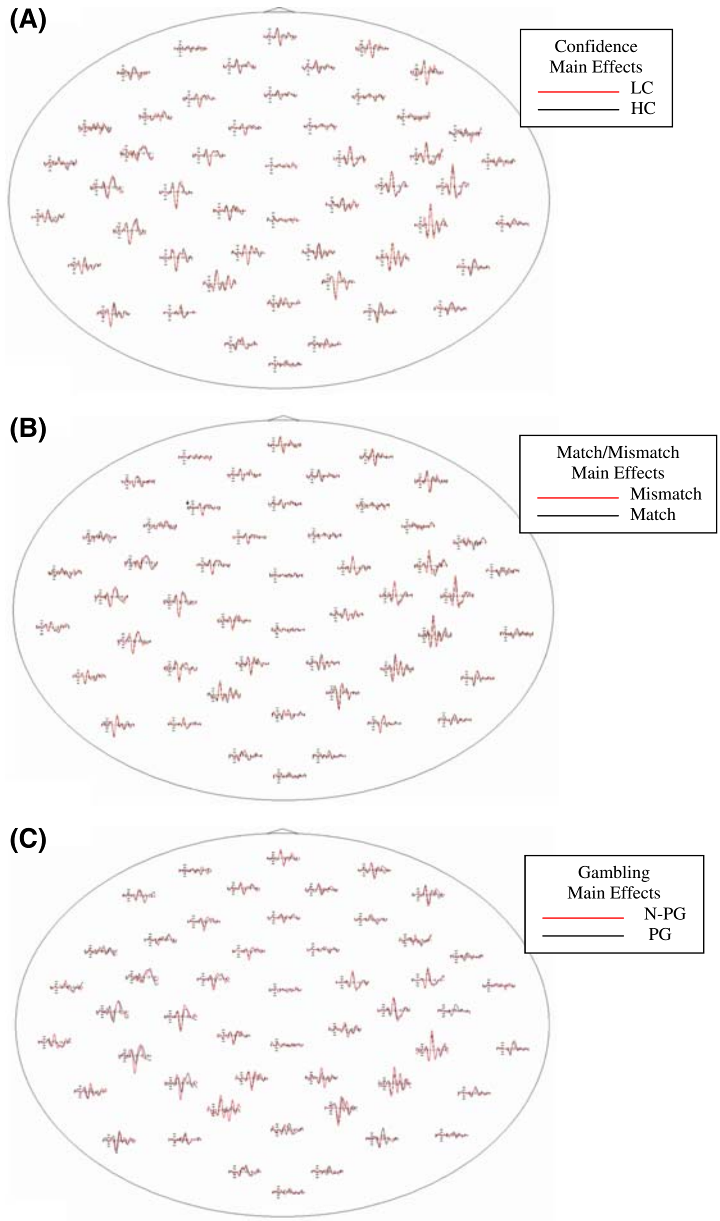

Fig. 3 Top view of grand averaged evoked magnetic fields by condition, for a subset of 50 channels depicting main effects of (**A**) confidence on accuracy, (**B**) match/mismatch and (**C**) gambling tendencies. LC, low confidence; HC, high confidence; N-PG, non-problem gamblers; PG, problem gamblers. The *x*-axis goes from 50 ms before to 450 ms after stimulus onset (with ticks every 100 ms), and the *y*-axis range (scale located at 0 ms on the *x*-axis) goes from –40 fT to 40 fT (with ticks every 20 fT)

inferior occipital-temporal junction region, and this effect was evident during the 150–200 ms ($F(1,17) = 11.78$, $P < 0.05$), 350–400 ms ($F(1,17) = 15.69$, $P < 0.05$), and 400–450 ms ($F(1,17) = 13.42$, $P < 0.05$) time intervals (see Figs. 2D–F, 3C). For all three-time intervals, brain activity in this region was highest for non-problem gamblers when they were presented with mismatched answers. The other conditions (non-problem gamblers when presented with correct answers and the problem gamblers regardless of type of answer presented) did not differ significantly from each other on brain activity in this region.

Behavioral results

Confidence calibration

Overconfidence scores were calculated by subtracting accuracy from confidence assessments in the behavioral session. Overall, average confidence was 79.2% ($SD = 10.0\%$), and average accuracy was 79.1% ($SD = 5.2\%$), leading to 0.1% overconfidence. This very good calibration is typical when well-defined question populations are randomly sampled, as they were here (Gigerenzer, 1991).

Problem gamblers ($N = 10$) were 4.6 percentage points more confident ($M = 81.3\%$, $SD = 7.5$) than non-problem gamblers ($N = 9$; confidence: $M = 76.7\%$, $SD = 12.2$) and were 0.8 percentage points more accurate (79.4% compared with 78.6%). As a result, problem gamblers were more overconfident by 3.8 percentage points compared to non-problem gamblers, a difference that was not statistically significant, $t(1,17) = 0.88$, $P > 0.05$. Similarly, the correlation between DIGS scores and overconfidence was not statistically significant, $r(17) = .35$, $p = .10$. The calibration results using the accuracy measures obtained in the MEG session were similar to those reported from the behavioral laboratory.

Reaction time

Reaction time was measured from the time the target was presented until the participant pressed the response button during the MEG session (see Fig. 4). Repeated measures 2×2 ANOVA showed significant main and simple effects of type of answer and confidence. Participants responded significantly faster, $F(1,18) = 7.12$,

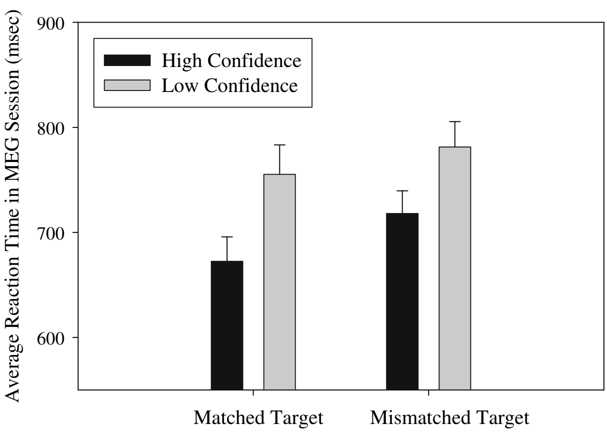

Fig. 4 Reaction time averages during MEG session. Bar graph shows significant effects of type of answer (matched or mismatched to answer) and levels of confidence (high or low confidence on their accuracy)

$P < 0.05$, when the target was a ‘‘match’’ compared to when it was a ‘‘mismatch’’ to the correct answer. Also, participants responded significantly faster, $F(1,18) = 48.92$, $P < 0.05$, when they were highly confident than when they had low levels of confidence in their accuracy. There was neither a significant interaction between type of target and levels of confidence, $F(1,18) = .855$, $P > .05$, nor a significant difference, $t(1,17) = 0.10$, $P > 0.05$, in reaction time between problem gamblers ($M = 724$ ms, $SD = 122$) and non-problem gamblers ($M = 728$ ms, $SD = 60$).

Discussion

The goals of this study were to describe the neural correlates of confidence judgments, and the differences in neural activations in response to such judgments between problem and non-problem gamblers, using a sample of undergraduate students who self-identified as frequent gamblers. Two results had bearing on these goals. First, during trials when participants were highly confident about a particular judgment they had higher right PFC activity than when they had low confidence. This difference occurred promptly (within 100 ms) after stimuli were presented about which a later judgment would be required. Second, non-problem gamblers demonstrated sensitivity to the correctness of the target (match versus mismatch) at the time a judgment was required. When presented with an incorrect answer (mismatch), non-problem gamblers had higher activity in the right inferior occipital-temporal cortex region. The problem gamblers' brain activity in this region, however, was insensitive to the correctness of the target at the time the judgment was required. The significance of these findings will be discussed in turn.

Neural correlates of confidence

Higher confidence was associated with increased activation of the right PFC within 100 ms of presentation of the target on the basis of which a later decision would be made. This is consistent with Henson et al. (2000) findings that confidence is associated with right dorsolateral PFC activity. It is interesting for two reasons that this difference in PFC emerged very early in the course of information processing. First, stimulus-related activation in PFC can occur within 100 ms (Foxe & Simpson, 2002), which is necessary for PFC to serve a theoretically important role as a modulator exerting top–down control of activity in other brain regions (e.g. Miller & Cohen, 2001). Second, in the present task, participants possessed the information relevant to the judgment from the time the states appeared, but could not prepare or engage in a decision response until the target appeared. The increased PFC activity was specifically associated with the decision, not the judgment, phase of the task, suggesting that this activity could be playing an important role in aiding task completion (e.g. Derrfuss, Brass, Neumann, & von Cramon, 2005). Response strategies in the present task seemed to differ under different degrees of confidence, and these response strategies were reflected in cognitive control that was mediated by the right PFC.

Gambling severity

Activity in the right temporal-occipital junction region was sensitive to differences in decision-making between problem and non-problem gamblers. This region is part of the right hemisphere attention system that supports identification of behaviorally relevant stimuli, and is most strongly activated when the observer is confronted with unexpected events (Corbetta & Shulman, 2002). It is not surprising, therefore, that the non-problem gamblers would show higher activity in this region when confronted with the wrong answer during the judgment phase of the task. What is potentially interesting, however, is that the problem gamblers were insensitive to the correctness of the target answer during the judgment phase. Behaviorally, problem gamblers differentiate less than non-problem gamblers between tasks characterized by control and tasks not characterized by control (Goodie, 2005). An important difference between problem and non-problem gamblers, therefore, may lie in the ability of the right hemisphere attention system to differentially respond to stimulus relevance in judgment tasks like the one used here.

Problem gamblers were found to be more overconfident than non-problem gamblers by Goodie (2005). This effect was observed to be in the same direction in this study, but not significantly so. Because of the small sample size relative to comparable behavioral studies, these results should not be interpreted too strenuously as either supporting or contradicting those of Goodie (2005).

The relationship between attention deficits and gambling problems has been examined in previous studies. Problem gamblers have more frequent and extreme reports of childhood attention deficits than do non-problem gamblers (Carlton et al., 1987). Attention deficits are significantly more common among pathological gamblers even after adjusting for such potentially confounding variables as substance abuse (Rugle & Melamed, 1993). Pathological gamblers have poorer performance in neuropsychological tests requiring higher order attention, higher ratings on self reported behaviors consistent with attention deficit disorder (Carlton & Manowitz, 1992), and deficits of executive functioning indicating problems with higher level attentional control (Rugle & Melamed, 1993). Attention deficits seen among problem gamblers may indicate a difficulty in extracting critical information from judgment-related gambling cues that could inform the individual about the level of risk associated with a particular behavior.

Limitations

The small sample size of this study limits the conclusions that can be drawn from it in at least two ways. First, a convenient median split was possible between non-problem gamblers on the one hand, and problem and pathological gamblers on the other hand. It was not possible to separate pathological gamblers from problem gamblers, which will be an essential step in clinical application of these findings. Future research should seek effects specific to pathological gamblers. Also, as noted, the small sample size is likely to have contributed to the statistical non-significance of the behavioral correlation between gambling pathology and overconfidence. Also, the route from this research to prevention or treatment programs for pathological gambling is not expected to proceed directly. The implications for treatment approaches based on cognitive biases and attentional factors are promising, but our results do not directly support or refute any particular intervention.

Summary

Undergraduate students who self-identified as frequent gamblers showed several behavioral and neural effects as a function of confidence judgment and degree of gambling problems. Higher confidence was reflected in increased right prefrontal activity. Matching targets were associated with increased activity in the medial occipital cortex, while mismatching targets were associated with increased activity in the medial left supramarginal gyrus. An interaction of pathology and match/mismatch was observed in the right inferior occipital-temporal junction region, showing more activity following a mismatch in non-problem gamblers, but not in problem gamblers. Taken as a whole, the data suggest that neuroimaging techniques with a high temporal resolution (such as MEG) are useful in distinguishing between patterns of neural responses under conditions of high and low confidence, and normal and problem gambling status. Based on these results, future studies should focus on the attentional systems of problem and pathological gamblers.

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