Using event-related brain potentials (brain waves) and autonomic measures to differentiate problem from non-problem gamblers

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Executive summary

This report presents a brief overview of the data collection and analysis for a project that sought to employ recent innovations in ambulatory technologies to examine the psychophysiological responses of both problem and non-problem gamblers during actual gambling activity in licensed club venues.

The results from the project did not find evidence for a hyposensitivity to wins and/or losses, or a hypersensitivity to rewards, among higher risk gamblers, as expected. A major contribution of the study is a much better understanding of the barriers, costs, merits and limitations of state-of-the art physiological equipment, which may guide future research.

Additional reporting related to this project is available upon request to the Victorian Responsible Gambling Foundation or the authors of this report. These report citations are:

- Gonsalvez, CJ, Barry, R, Blackman, R 2013, *Using event-related brain potentials (brain waves) and autonomic measures to differentiate problem from non-problem gamblers*, unpublished final report for the Victorian Responsible Gambling Foundation.

- Barry, R J & Gonsalvez, C J 2014, *Using event-related brain potentials (brain waves) and autonomic measures to differentiate problem from non-problem gamblers*, unpublished addendum to final report for the Victorian Responsible Gambling Foundation.

Literature review

Problem gamblers continue to gamble excessively, despite repeated and severe negative consequences (American Psychiatric Association, 2013), an apparently illogical pattern of behaviour that is difficult to understand.

The impact of problem gambling is greatly accentuated because it is associated with increased risk of anxiety, mood and personality disorders, substance abuse disorders and suicide (Delfabbro & LeCouteur 2005; Potenza, Fiellin, Heninger, Rounsaville & Mazure 2002; see Raylu & Oei 2002 and Shaffer & Korn 2002 for comprehensive reviews on the harms associated with this disorder). It is estimated that this disorder affects around 0.7 per cent of the Australian adult population, with a further 1.7 per cent of the population at risk of developing a harmful addiction to gambling activity (Productivity Commission 2010).

Research on the problem gambling population has typically focused on the influence demographic, personality, social, and cultural factors have on associated psychopathology. While these factors are important in understanding the individual and environmental impact on problem gambling behaviour, much less attention has been directed to the psychophysiological mechanisms that occur during gambling (Lole, Gonsalvez, Blaszczynski & Clarke 2012), which have the potential to elucidate the underlying mechanisms that contribute to this pattern of behaviour.

Currently, the dominant physiologically based theory is that factors such as the 'buzz' or arousal associated with gambling activity, rather than the monetary gains, plays a key role in the development and maintenance of gambling, including problem gambling (Blaszczynski, & Nower 2002; Brown 1986; Jacobs 1986; Sharpe, Tarrier, Schotte, & Spence 1995). Specifically, problem gamblers are posited to be hyposensitive to losses and/or wins, or hypersensitive to wins; however, these hypotheses remain unverified.

Research investigating incentive value processing in problem gamblers using neuroimaging or psychophysiological methods is relatively scarce, and preliminary results are by no means consistent (e.g. de Ruiter, Veltman, Goudriaan, Oosterlaan, Sjoerds & van den Brink 2009; Goudriaan, Oosterlaan, de Beurs & Van den Brink 2006; Hewig, Kretschmer, Trippe, Hecht, Coles, Holroyd & Miltner 2010; Miedl, Fehr, Meyer & Herrmann 2010; Oberg, Christie & Tata 2011; Reuter, Raedler, Rose, Hand, Glascher & Buchel 2005; van Holst, Veltman, Büchel, van den Brink & Goudriaan 2012).

Moreover, technical difficulties in attaining reliable recordings during live gambling, difficulties in gaining access to gambling sites to obtain live recordings, and a range of ethical concerns affecting the recruitment of research participants, have combined to severely restrict physiological gambling research. Most physiological research has been conducted in laboratories in simulated gambling situations using quasi-gambling tasks that may not sufficiently resemble true gambling activity. For example, in such scenarios there is no risk of monetary loss, which provides a pale comparison to real world gambling

scenarios, where large sums of money can be lost and gained (Gainsbury & Blaszczynski 2010).

In addition to this, the majority of autonomic research on gambling has focused on tonic measures of arousal, which average physiological responses over relatively long periods of gambling activity (e.g. Carroll & Huxley 1994; Coulombe, Ladouceur, Desharnais & Jobin 1992; Diskin & Hodgins 2003; Griffiths 1993; Krueger, Schedlowski & Meyer 2005; Meyer et al. 2000; Meyer et al. 2004; Sharpe 2004; Sharpe, Tarrier, Schotte & Spence 1995). This approach is problematic for a number of reasons. For example, the number and nature of win and loss events during the gambling period are not consistent, but are likely to influence results.

Tonic measures are also sensitive to a range of other confounding influences, including social interactions and the consumption of legal and illegal drugs. It is also more difficult to interpret tonic between-group differences since different behaviours and practices are observed among problem and non-problem gamblers (Blaszczynski, Sharpe & Walker 2001), and the outcomes from such diverse betting patterns may account for any physiological changes observed. Moreover, research that uses tonic methodology has a limited capacity to elucidate the incentive value processing of both problem and non-problem gamblers, specifically, whether they are differentially sensitive to reward and/or punishment stimuli.

Study aims

The current study capitalises on the recent advent of sophisticated ambulatory equipment used for physiological recording in order to attempt a ground-breaking study that endeavours to meet the challenges facing the current field of gambling research. In order to overcome the shortcomings of previous research, the physiological responses that occur to individual instances of outcomes commonly encountered during gambling were examined.

There are many forms of gambling; however, the most problematic type is arguably gambling on electronic gaming machines (EGMs; also known as poker machines), since the majority of individuals who seek treatment for gambling problems report addiction to this gambling medium (Abbott 2006; Dowling, Smith & Thomas 2005; Productivity Commission 2010). This form of gambling is associated with a faster progression of the disorder (Breen & Zimmerman 2002) and more severe symptoms (Petry 2003). Thus, the responses that occur during gambling on this particular medium were the focus of the current study.

The study attempted a comprehensive and systematic examination of physiological responses (including event-related brain potentials or ERPs, electrodermal and electrocardiac activity) across the range of EGM events (bets, wins, losses, fake wins and features) for both problem and non-problem gamblers. Data were collected as club patrons gambled live on EGMs within a licensed gaming venue, so that responses to true gambling activity could be investigated. A major advantage of using such objective psychophysiological measures (rather than self-report measures) to test between-group differences in reward and punishment sensitivity is that they are less susceptible to deliberate and unintentional distortions.

The project was part of a larger program of research that aims to establish a physiological signature that is characteristic of problem gamblers in order to facilitate the development of a test that can provide early identification of persons at risk. Such an initiative has high impact due to its potential to uncover signature differences that set problem gamblers apart, and thereby help early identification and intervention for this disorder.

As an essential first step, the current project aimed to:

i.   examine the feasibility and reliability of attaining phasic physiological measurements to rapidly changing gambling outcomes during live gambling in clubs

ii.   determine if a combination of event-related brain potentials (ERPs), skin conductance (SC) and heart-rate (HR) measures to win- and loss-events during gambling on an EGM could help differentiate problem from non-problem gamblers while they gambled with their own money in an actual club environment.

Methods

All participants were patrons who visited the Easts Rugby League Club, Bondi, during 2012 and 2013. The study was advertised with flyers posted within the gaming venue. Individuals who were interested in participating approached the researchers to volunteer for the study. In total, data were collected from 83 individuals. Data from three participants were excluded due to computer or equipment failure during the recording phase. Of the remaining 80 participants, 32 were categorised as low-risk gamblers, 30 as moderate-risk gamblers, and 18 as problem gamblers, according to scores on the Problem Gambling Severity Index (Ferris & Wynne 2001).

Ethics approval for the current research project was granted by the University of Wollongong Human Research Ethics Committee and the Victorian Department of Justice Human Research Ethics Committee. Participants were fully informed of the study protocol before they participated and were advised that they were free to withdraw from the study at any time. Written consent was obtained from each participant before recordings commenced.

Recordings were conducted individually within the gambling club setting. Participants were fitted with the ambulatory monitoring devices to record their SCL, HR (Groot, de Geus & de Vries 1998) and EEG. The EMOTIV EEG headset was employed in an attempt to capture ambulatory EEG and to investigate the potential for ambulatory ERP. The device is a multi-channel (14 channels based on the international 10–20 system for EEG recording) portable EEG system.

Participants were then allowed to select their preferred EGM and were seated in the player position, with their non-dominant hand resting on their lap. Once the recording commenced, the researcher remained within the area at a distance to monitor the equipment, however, they did not interact with the participant. Instead, a high-speed GigE video camera recorded the screen of the EGM so that the events could be later matched to physiological responses offline. Participants were instructed to play the EGM however they wished, and were free to move between machines, pause, or cease play at any time.

In accordance with ethics approval guidelines, the researcher made no attempt to influence the gambling behaviour of the participant, but acted as a passive observer. A maximum of 30 minutes of play was recorded (although participants could cease gambling earlier, if they chose to), and participants received two $20 bistro vouchers for their participation.

At the end of the gambling session, participants completed the Problem Gambling Severity Index (Ferris & Wynne 2001) on site, and were given additional questionnaires, including the Behavioural Inhibition Scale and the Behavioural Approach Scale (Carver & White 1994) and the Informational Biases Scale (Jefferson & Nicki 2003) to complete at home and return via

post. To facilitate free disclosure of problem gambling behaviours, no identifying data (e.g. names or addresses) were collected. Instead, codes were used to match physiological with questionnaire data.

The current study employed a range of data analytic methods to reduce the effects of artefacts. Of key importance to the analyses of physiological data is the need for exact time synchronisation (time-locking) of event occurrence on the ongoing recording of physiological activity. Because ERPs vary at the millisecond level, a high level of accuracy to time-lock events (wins/losses) and physiological responses is essential.

Video files derived from the GigE device were reviewed frame by frame and events manually coded on a digital event time sheet. Time markers were inserted for each event type, including losses, fake wins (when returns were less than amount bet), wins, and features (EGM outcomes in which free spins, second screen games, scatters or substitutes are 'won'. They can last for a period of up to several minutes and generally result in larger amounts of money/credits being returned to players compared to regular wins, since any winning combinations that occur within them are typically multiplied). These markers were then used to synchronise event onset with the physiological data.

As the sampling rate of the camera and AMS device were not consistent or aligned, SCL and HR values were calculated using a custom MATLAB script, such that the data value represented the relevant proportion of the 100 ms period. Values were zeroed around the event for comparison of responses at the event time between participants. MATLAB automated scripts were used to identify and remove any events with extreme time variations between the time a bet was placed and the time when the reels stopped spinning, signalling an extended spin or unusual event.

Analysis for the autonomic variables (i.e. electrodermal and electrocardiac activity) measured in this study was extremely time consuming. Skin conductance responses (SCRs) to features, wins, losses and fake wins were recorded during live gambling and later separated based on gambling outcomes. These responses to gambling outcomes, including wins, losses, fake wins and features were subjected to statistical analyses.

As with the data for the autonomic variables, different outcome types were isolated from within the EEG data. To date, only ERP data from subjects without features have been analysed. Once event markers were inserted onto the physiological recording, electroencephalogram (EEG) data were low-pass filtered below 30 Hz (24 dB). Epochs ranging from stimulus onset to 700 ms post-stimulus were created for each participant over each outcome type and the 14 recording sites (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4). These data were then baseline corrected relative to the pre-stimulus interval (100 ms).

Trials that contained muscle or other artefact (±100 µV) were manually identified and excluded from further analysis. Once all artefacts were removed from the data, event-related potentials (ERPs) were created by averaging the epochs for four event types together for each participant. The event types included two outcomes, wins (W) and losses (L), and two times, time 1 (T1) and time 2 (T2). Time 1 was marked as the time when each bet was placed and time 2 was marked when the win/loss outcomes were evident (note, only the loss that occurred immediately before each win was selected for comparisons with win events). Due to the high occurrence of artefact in the data, a sufficient number of EEG epochs were able to be derived only for seven problem gambler and a matching seven non-problem gambler participants without features.

The ERP responses from each group (problem gamblers and non-problem gamblers) and event outcome (W, L) were analysed together for direct comparison; however, these comparisons were analysed separately at T1 and T2. For each time-based analysis, we subjected data from the two groups (problem gamblers and non-problem gamblers) following the two outcome types from each of the 14 channels over 700 data points (i.e. one data point for each ms) to a temporal Principal Components Analysis (PCA), using the ERP PCA Toolkit in MATLAB (version 2.23; Dien, 2010). All 90 components were rotated using VARIMAX rotation with Kaiser normalisation. The first two components were most informative for each time-based analysis, carrying 52.3 per cent and 9.8 per cent of the variance in the data, respectively, at T1, and 27.3 per cent and 18.6 per cent of the variance, respectively, at T2. The results for each PCA are discussed in the next section.

Outcomes and limitations of the proposed approach

Despite promising results from pilot studies, the ERP data obtained from the equipment at the gambling venues were poor. The response profile of ERP components at time 1 should be expected to be similar between losses (LT1) and wins (WT1), but may differ between the problem gambler and non-problem gambler groups. The results of the PCA showed that the ERP components elicited at the beginning of the spin are relatively similar within groups, and differ substantially between groups. At time 2, any differences in responding to wins and losses should begin to emerge.

The most obvious feature of the PCA components elicited at this time is that the problem gambler group shows larger responses (i.e. greater amplitude voltages) in both components identified, to losses compared to wins, an effect not apparent in the non-problem gambler group. This effect matches a similar loss > win effect for problem gamblers (and not non-problem gamblers) in the electrodermal data.

Although these results are encouraging, the morphology of the ERPs did not match expectations (i.e. amplitudes were small and peak waveforms were hard to identify in a reliable manner) and the data obtained are of reduced quality compared to the data collected during the piloting phase of the study. No evidence was found to support the hypothesis that higher risk gamblers are hyposensitive to losses and/or wins, or hypersensitive to wins.

The reasons for these unsatisfactory results are unclear and are currently being systematically investigated. Although the results obtained in the current program of research are encouraging, the data processing associated with it has highlighted a general reduction in data quality relative to that obtained in laboratory-based pilot testing sessions. The exact cause(s) of this quality reduction is uncertain, but it appears that it was primarily caused by inconsistent timing of events. This is perhaps due to the relatively slow recording speed of the camera used and the associated difficulty in exactly 'catching' the occurrence of outcomes, as well as the lack of associated auditory information that would aid in the more accurate coding of win and loss outcomes.

Moreover, the tedious nature of the human processing required to translate visual scenes to time markers adds an overlay that contributes to error. Future research should avoid this human translation step and automate timing where possible. Unfortunately, this was not achievable in the current project because clubs would not allow anything to be attached to an EGM. Nevertheless, a better system than the one outlined in this report is necessary.

In addition to the timing problem, the general, rather chaotic, club environment at the EGM is a far cry from normal, somewhat sanitised, laboratory conditions. Although we do not believe this to be the primary problem with the current study, it undoubtedly contributed to noise in the data.

While we have concentrated our efforts to date on wins and losses from data without features, and differences in how problem gamblers and non-problem gamblers process these, we are still interested in an intensive re-look at the effects of features. Given that these outcomes occur over an extended period of time compared to other outcome types, the timing problems outlined above might be reduced sufficiently to generate useful outcomes.

Two manuscripts (one on electrodermal and the second on HR data) based on preliminary analyses have been submitted as appendices in the 2013 report by Gonsalvez et al. At some time in the future, we hope to be able to more carefully examine the robustness of these findings and will report them if they are reliable and have clinical significance.

Although the time-locked data has yielded poor results, it is possible that frequency-analysis of the electroencephalograph (EEG) may reveal differences between gambling events (wins and losses) and types of gamblers. The EEG data is currently being subjected to further analyses – steps that were not part of the original project's protocol.

The project was a pioneering attempt to record physiological measures including ERPs, electrodermal and cardiac activity to wins and losses during live gambling in licensed clubs. As with many first-time initiatives, several barriers and challenges to conducting the research were encountered. Two of the main challenges were identified. One of these challenges was the large number of artefacts that needed to be filtered out by sophisticated and painstaking analyses. The other main challenge was the less than satisfactory outcomes from emerging ambulatory technologies to enhance the reliability and robustness of measurements when recorded in a club setting.

The preliminary results obtained from this dataset did not find evidence for a hyposensitivity to wins and/or losses, or a hypersensitivity to rewards, among higher-risk gamblers, as predicted. In addition to the outcomes mentioned above, a major contribution of the study is a much better understanding of the barriers, the cost (in terms of time) and the merits and limitations of state-of-the art physiological equipment. In this context, the study has paved the way for more effective and productive research to be conducted in future.

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