Capturing SCL and HR changes to win and loss events during gambling on electronic machines

Benjamin L. Wilkes, Craig J. Gonsalves, Alex Blaszczynski

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The role of physiological arousal is central to theories about the onset and maintenance of gambling behaviours including problem gambling. The range of possibilities suggested include tonic underarousal and phasic abnormalities such as hypersensitivity to reward and/or reduced sensitivity to negative consequences associated with losses. Among the various types of gambling, electronic gambling machines (EGMs) are associated with the large majority of gambling related problems. The demonstration that physiological changes associated with rapidly occurring win and loss events during electronic gambling can be reliably captured is fundamental to further progress in the psychophysiology of gambling. The current study monitored electrodermal and cardiac activities of twenty-four healthy participants to event outcomes (losses, fake wins, small wins and big wins) during a task on a real EGM. The results demonstrated that it is possible to reliably capture the profile of physiological changes as they occurred in real time to the many different win and loss events during electronic gambling. Relative to baseline levels, win events produced significant increases in skin conductance levels, (but not in HR) whereas loss events produced no significant changes. The study has important applications for further experimental and clinical research.

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1. Introduction

The physiological changes generated from gambling have been considered as major reinforcers for participation in gambling activities for both recreational and problem gamblers (e.g., Dickerson, 1983; McConaghy et al., 1991; Moodie and Finnigan, 2005). Increases in arousal experienced as a rewarding or excitement by the gambler (Anderson and Brown, 1984) are theorised to attract individuals to gambling in general, and possibly differentiates problem gamblers from healthy controls (Dowling et al., 2005; Wulfert et al., 2005). Theoretical conceptualisations are not clear, however, whether the reinforcing properties associated with arousal stem from specific events within gambling (e.g., wins, near-wins or losses) or whether a potentially heightened arousal state (tonic rather than phasic levels) that lasts during the entire period of gambling may have inherent reinforcing properties. If elevated tonic levels of arousal are reinforcing by themselves to some individuals, desired arousal states may be generated by the possibility rather than the actuality of winning.

I.1. Effects of gambling on tonic physiological activity

Physiological changes in response to gambling have commonly been investigated by comparing cardiac activity pre- to post-sessions of gambling (i.e. tonic changes). Exposure to gambling generally increases heart rate (HR) (Anderson and Brown, 1984; Coulombe et al., 1992; Coventry and Norman, 1997; Diskin et al., 2003; Griffiths, 1993; Krueger et al., 2005; Leary and Dickerson, 1985; Meyer et al., 2000). In addition, gamblers who have won overall following gambling have been shown to experience larger HR increases (Coventry and Hudson, 2001; Coventry and Norman, 1997).

Changes to tonic HR may not be the key to the psychophysiology of gambling behaviours. Some authors argue that there may be more reliable measures of arousal and that, at least in certain circumstances, HR changes may not reflect arousal changes (Barry and Sokolov, 1993; Rushby and Barry, 2006). The research within the gambling domain does not support the relevance of using other physiological measures. Researchers have observed tonic increases in skin temperature (Roby and Lumley, 1995), electrodermal activity (Diskin et al., 2003; Diskin and Hodgins, 2003; Sharpe et al., 1995; Sharpe, 2004) and cortisol levels (Krueger et al., 2005; Meyer et al., 2000) upon exposure to gambling and its cues.

Although the research on tonic HR is fairly consistent, the interpretation of these results is problematic. Because these measures (e.g., HR) are averages derived following relatively long periods (several minutes) of gambling, they are confounded by factors, such
as the context or sequence of wins and losses experienced, physical movements, and/or use of chemical substances (caffeine/nicotine/ethanol) used prior to or during the gambling session. Additionally, because problem gamblers bet more frequently at higher stakes than non-problem gamblers (Blaszczynski et al., 2001), increased tonic HR may be due to these behaviours rather than to true, between-group differences. This position has also been supported by other researchers (Goudriaan et al., 2004). Finally, researchers have also argued that problem gambling may be a consequence of hypersensitivity to rewards (wins) and/or insensitivity to punishments (losses) during gambling (Damasio, 1996; Reuter et al., 2005). All of these factors underline the importance of developing a systematic method of capturing physiological activity in real time, at the phasic level, in response to win and loss events in order to advance our understanding of how arousal effects can influence gambling behaviour in healthy individuals and in problem gamblers.

1.2. Effects of win and loss events on phasic physiological activity

There is limited research (only 4 studies were identified) on the immediate physiological effects of win and loss events during gambling in both healthy and problem gambling populations. Of specific relevance is the examination of psychophysiological responses to wins and losses during play on electronic gambling machines (EGMs). EGMs deliver an intermittent ratio of winning and losing events, which are pseudo-randomly configured so that the “house” wins in the long term (Walker, 2004). EGMs have been called the crack-cocaine of gambling because of their addictive potential (Dowling et al., 2005). Among other gambling activities, they also effect the most harm on the gambling community (Blaszczynski et al., 2001; Walker, 2004).

Dickerson et al. (1992) monitored HR for 10 high frequency EGM gamblers in a club setting. When cardiac activity, averaged for one-minute periods, was compared for no wins, small wins and big wins, no significant differences occurred although a trend for increased heart rate to small wins and more so for big wins was observed. The poor temporal resolution (averages over minutes rather than seconds) together with the weak statistical effects observed, limits the value of the study. Moodie and Finnigan (2005) examined heart rate differences between frequent, infrequent and non-gamblers during EGM play. Frequent gamblers had greater HR increases than non-gamblers to individual winning trials, however, there was no significant difference between frequent and infrequent gamblers. A comparison of winning versus losing events was not presented; however, amount won following individual bonus shots was a significant predictor of HR changes (Moodie and Finnigan, 2005).

The importance of winning was similarly reflected by the tonic data which revealed that those participants who won overall experienced the greatest increases in HR throughout play. A pilot study by Wilkes et al. (2009) examined changes to skin conductance levels (SCL) and inter-beat-intervals to win and loss events while 12 university students played on an EGM in a laboratory setting, for entertainment vouchers as the incentive. The results indicated that wins produced larger SCRs that peaked between four and eight seconds after the outcome and returned to baseline around 15 s post-event. Losses, on the other hand, were associated with marginal reductions of SCL that were not significant. No significant differences were observed for HR.

Finally, Goudriaan et al. (2006) recorded HR changes and (skin conductance responses) SCRs to wins and losses during the Iowa Gambling Task (Bechara et al., 1994). The normal control group exhibited greater increases in HR immediately following winning events than the problem gamblers. No differences in HR or SCRs to losing events were observed.

In summary, when real gambling activity was monitored, win events were associated with HR increases immediately after (seconds after a win in the study by Moodie and Finnigan, 2005; and a minute after a win in the study by Dickerson et al., 1992). When simulated gambling tasks were used, SCL appeared to be the more sensitive index (Wilkes et al., 2009). Results for between-group differences were inconsistent. Whereas one study found enhanced HR reactivity for frequent gamblers (vs. non-gamblers; Moodie and Finnigan, 2005), another reported decreased HR reactivity to wins for problem gamblers (Goudriaan et al., 2006).

1.3. Clinical implications

It is well established that problem gambling not only leads to dire financial consequences but also to an increased risk of mood disorders, abuse of alcohol, nicotine or other drugs, and suicide (Delfabbro and LeCouteur, 2005; Potenza et al., 2002). In addition, problem gambling has a negative impact (e.g. crime, financial/relationship distress) on family, friends and the greater community (Productivity Commission, 1999, 2009). Converging evidence from several domains indicates that biological factors, especially arousal mechanisms, are likely to have an important role to play in the development and maintenance of problem gambling (Goudriaan et al., 2004; Meyer et al., 2000; Sharpe, 2002). Hence a clearer understanding of the psychophysiology of gambling behaviours, particularly on EGMs, has the potential to have a major clinical impact.

1.4. The present study

The present study was designed to capture psychophysiological changes that were event-related (e.g., wins vs. losses) using the time-locked averaging procedure that is commonly used in the derivation of event-related brain potentials or ERPs (see Picton et al., 2000). The assumption within this approach is that each epoch (e.g., 10-s sweep) contains the signal (e.g., true change associated with a win) embedded within noise (changes associated with uncontrolled external or internal stimuli such as external noises, movement, or expectancy). When multiple epochs are time-locked to the event of interest (win/loss) and averaged, the signal is enhanced because amplitude changes (e.g., SCRs) reliably occur around the same time whereas uncontrolled, random changes get averaged out. The event-related averaging technique is critical to studying psychophysiological changes in real-life gambling, especially gambling on EGMs. This is because specific phasic activity (e.g., SCRs) can be isolated and measured precisely in a highly controlled laboratory environment, but not in a gambling club where a range of stimuli from neighbouring persons and machines randomly contaminate true changes associated with wins and losses during the gambling task. Because these event-related changes are accurate at the second-by-second level (although not at the millisecond level), they will be referred to as phasic changes.

The current study, we believe, is the first study to examine in a comprehensive and systematic manner, physiological changes on a second-by-second basis to all four main EGM outcomes, namely, losses, fake wins (where a return is paid, but it is less than that has been wagered on an outcome), small wins, and big wins. Second, the study examines tonic and phasic activity using HR and SCL measures. Third, the effect of stakes (low vs. high) on HR and SCL are examined. It was hypothesised that: a) wins but not losses would evoke SCL and HR increases (e.g., Wilkes et al., 2009), b) as compared to smaller wins, big wins would be associated with larger increases in SCL and HR (Dickerson et al., 1992; Moodie and Finnigan, 2005), c) the higher stakes condition would produce greater increases in SCL and HR compared to the low stakes condition (e.g., Blaszczynski et al., 2001; Goudriaan et al., 2006), and d) that the HR and SCL measures would complement rather than replicate each other (Diskin et al., 2003; Sharpe et al., 1995; Wilkes et al., 2009).
2. Method

2.1. Participants

Twenty-four university students (17 females; 7 males) from introductory psychology classes responded to a university intranet-based advertisement to complete the study for research participation credits. The mean age of participants was 21.04 years (SD = 5.2). No participants reported to have played an EGM in the last month.

2.2. Design

The study followed a 4 (events) × 5 (time intervals) repeated measures design with skin conductance level (SCL) and heart rate (HR) as dependent variables.

2.3. Materials

2.3.1. Electronic gambling machine (EGM)

Participants used a real (not computer simulated) one-cent denomination EGM named “Alchemy” supplied by Aristocrat Technologies Australia Ltd© 2003. The EGM featuring a 5 × 3 matrix, allows players to bet between one and 20 credits across 1, 5, 10, 20 or 25 lines (thus bets range from 1c to $5.00). Similar EGMs are currently in use in many licensed gambling venues today.

2.3.2. Measures of gambling behaviour

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The South Oaks Gambling Screen (SOGS; Lesieur et al., 1991). The SOGS is the most widely used instrument in both clinical and non-clinical populations and has good psychometric properties (Lesieur et al., 1991).

2.3.3. Gambling cognitions

The Informational Biases Scale (IBS; Jefferson and Nicki, 2003) was used to measure cognitive distortions such as control and gambler's fallacy. The IBS has 25 items, has adequate psychometric properties, and is well suited to examine cognitions associated with gambling.

2.3.4. Gambling urges

The Gambling Urges Scale (GUS; Raylu and Oei, 2004) was given to measure the frequency and intensity of gambling urges as experienced by participants post-gambling activity. The measure has six items and was chosen for its good validity and reliability and has been used in non-clinical populations (Raylu and Oei, 2004).

2.3.5. Psychophysiological measures

SCL and HR were recorded using the ambulatory monitoring system AMS-36 (Groot et al., 1998). The AMS-36 device weighs 225 g and has dimensions of 120 × 65 × 32 mm, which allow for unobtrusive recording. Cardiac activity was measured by two electrodes: one placed at mid-sternum and the other on the left side of the subject between the ninth and tenth rib, and was recorded by measuring R–R intervals (accurate to 1 ms) throughout the recording period. For statistical analyses and figures these data were then used to recompute HR (beats per minute) as this measure varied at one-second intervals. SCL was obtained with a constant voltage of 0.5 V from two silver–silver chloride electrodes attached to the palmar surface of the middle phalanx of the second and third fingers of the non-dominant hand using an electrolyte of 0.05 M NaCl in an inert viscous ointment base. The system uses a 16-bit AD converter for SCL measurement, with a resolution of 0.0125 μs. The AMS has a 100 ms sampling interval. SCL was recorded at 500 ms intervals, but these data were reduced to second-by-second values for the figures.

2.4. Procedure

The Ethics Committee of the University of Wollongong granted approval for the research project and written informed consent was obtained from each participant before commencement of the study. Experimental sessions were conducted individually in a laboratory setting. Participants were seated throughout the recording sessions and were instructed to restrict their motor activity throughout the recording period to pressing the EGM’s play buttons with their dominant playing hand. Participants were instructed to rest their non-playing hand on their corresponding leg.

Participants played on the EGM in three betting conditions: low, high and free stakes. All conditions allowed participants to wager on up to 25 lines, simulating real-life conditions. In the low stakes condition, the bet-size was restricted by restricting participants to a low multiplier option (factor of 2) while participants chose a higher multiplier option (factor of 4) in the high stakes condition. In effect, bets could range between 2 and 50 credits per trial during the low stakes condition and between 4 and 100 credits in the high stakes condition. In the final “free stakes” condition, participants were free to vary bets from trial to trial with bets ranging from 2 to 100 credits. The participants played the low and high stakes conditions in counterbalanced order, with the free stakes condition always completed as the final session of testing. Physiological activity was recorded throughout the entire experiment. Participants had two-minute rest breaks before the experiment began, between the stakes conditions and at the end of the experiment. Physiological data during these two-minute breaks were extracted as measures of tonic activity.

As in real-life gambling, participants self-regulated the rate at which they placed bets and activated outcomes, hence inter-trial intervals were not controlled by the experimenter. Because each event was recorded, post-hoc analyses revealed that for the 45 min of gambling activity, the mean number of trials for participants was 431.63 (SD = 76.78), with a mean inter-trial interval of 6.25 s.

Consistent with ethical guidelines, participants were prevented from gambling with their own money. Each participant was provided with 5000 credits ($50) at the beginning of the schedule and was informed that they would win a cinema ticket (valued at $11.70) if they had more than 7000 credits ($70) at the end of any of the three, 15-min blocks. Fifty percent of participants had more than 7000 credits at the completion of at least one session of play and won an entertainment voucher. As in live gambling, participants were able to gamble or “double-up” their wins by predicting the colour or suit of the next card. Participants were given a trial demonstration on the EGM to ensure they were completely familiar with their response requirements and the equipment before the experiment commenced.

A video camera captured the EGM’s screen to allow the researcher to monitor trial-by-trial choices made by the subject. Seated in an adjoining section of the laboratory, the researcher marked events with button presses on a computer keyboard. The researcher coded the outcome of each trial into four event types: losses, fake wins, small wins and big wins. An event was marked as a “loss” if no return was paid to the player; a “fake win” if a return is paid, but that the amount of credits returned was less than that wagered; a “small win” if the outcome of the bet resulted in an increase of credits up to five times that wagered and as a “big win” if the amount returned was more than five times that which was wagered. Differentiation between event types was made easy because, as in real life, the amount wagered and the winning credits were prominently displayed on the screen after each trial. Big wins (or features) were easy to identify because of distinct auditory and visual displays associated with these outcomes.

Participants who reported smoking, alcohol or medication use in the two hours prior to physiological testing were excluded. On completion of the gambling task participants were given the questionnaires (SOGS, IBS, and GUS) to complete. To preserve the anonymity of participants, all questionnaires were de-identified and
matched to the physiological data at a later date. All participants were debriefed, given information about problem gambling and contact numbers for problem gambling services at the completion of the study.

3. Data analysis and results

3.1. Behavioural results

Table 1 displays the gambling outcomes at the completion of the 15-min gambling sessions. Ten, nine and six participants ended the sessions as winners in the low, high, and free stakes conditions respectively. An equal number of participants won the required credits to win vouchers in the low (2) and high stakes (2) conditions; however, most vouchers were won in the free stakes condition (8) that allowed the combination of low and high stakes play.

Table 2 shows the frequency of event type during sessions of play for the participants.Across stake conditions, big wins were the most infrequent event type across sessions occurring 2% of the time, followed by small wins (13%), fake wins (20%) and losses (65%). The frequency of these event types indicated that a return was paid to the participant once every three wagers, but that an actual win (i.e. small win or big win) occurred less frequently (15%).

Researcher response time to code win and loss events and accuracy was assessed by recording an actual gambling session and simulating the sequence of trials and outcomes on a computer task. The researcher completed the recording simulation task on 10 occasions comprising of 202 trials. No errors were recorded for any event type in each of the completions of the simulated recording task. On average, across event types, the response time between event outcomes and event-marking was close to one second (On average, across event types, the response time between event outcomes and event-marking was close to one second). The researcher was able to simulate the sequence of trials and outcomes on a computer task, with the researcher completing the recording simulation task on 10 occasions comprising of 202 trials. No errors were recorded for any event type in each of the completions of the simulated recording task. The researcher was able to simulate the sequence of trials and outcomes on a computer task.

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3.2. Phasic responses to EGM play

A 21-s epoch for each event, commencing 5 s before to 15 s following the marking of the event outcome was isolated from the ongoing physiological recording to be subjected to further analyses. Data were then averaged separately for each event type. Group means plotted as a line graph over the 21-s epoch (Fig. 1). Based upon the results of the pilot study (Wilkes et al., 2009), an extended time epoch was captured in order to identify peaks of response to stimuli (events) and capture activity associated with large wins that could extend over a longer duration. Post-event analyses were therefore extended from 12 to 16 s compared to the pilot study (Wilkes et al., 2009), with five time intervals across the 21-s epoch calculated: baseline (B; 4 to 1 s prior to the event taking place); an elevation of activity soon after the occurrence of the outcome [PE1; 1–4 s post-event], activity peaking [PE2; 5 to 8 s post-event] and then a gradual return to baseline activity [PE3; 9 to 12 s post-event, and PE4; 13 to 16 s post-event]. Because of similar morphologies for HR and SCL, identical time periods were used for both measures. For purposes of statistical analyses, the data within each time period was collapsed to a single mean, yielding five data points for the 21-s epoch. The event markers for all events were adjusted by 1 s to accommodate the reaction time lag of the researcher to mark the events.

HR and SCL data were separately subjected to repeated measures ANOVA. Because we were concerned about signal-to-noise ratios and because there were sometimes only few events in some cells (e.g., big wins in low/high stakes), we initially collapsed the data across the three stake conditions (low, high/free) and performed an ANOVA where the two factors were 4 event types (losses/fake wins/small wins/big wins) × 5 Time intervals (B, PE1, PE2, PE3 and PE4). In order to determine differences relative to baseline, planned contrasts between the baseline (B) and each post-event segment (PE1, PE2, PE3 and PE4) were also conducted. For the event factor, three hypotheses were tested: small wins vs. losses, losses vs. fake wins, and small wins vs. big wins. All contrasts computed were a-priori contrasts based on a single degree of freedom. These analyses handled sets of contrasts in such a way that each contrast in the set remained linked with just its specific error term (O’Brien and Kaiser, 1985). Corrections for homogeneity of variance (sphericity) that typically apply to repeated measures designs therefore were not required (Tabachnick and Fidell, 1989).

3.2.1. Small wins vs. losses

As shown in Fig. 2, small wins across time periods were associated with larger SCLs than losses, F(1,23) = 20.23, p < 0.001, η² = 0.47. Event × Time interactions were significant: for B vs. PE1, F(1,23) = 36.63, p < 0.001, η² = 0.61; for B vs. PE2, F(1,23) = 25.67, p < 0.001, η² = 0.53; for B vs. PE3, F(1,23) = 18.01, p < 0.001, η² = 0.44; and for B vs. PE4, F(1,23) = 7.35, p < 0.05, η² = 0.24. Overall, the results indicate that significant elevations of SCL were produced immediately following win events (PE1), compared to losses, and that the increased electrodermal activity was maintained above baseline up to 16 s post-event (PE4). In contrast to wins, SCL to losses showed little if any change.

There were no significant main or interaction effects for HR.

3.2.2. Fake wins vs. losses

For the SCL data, an overall main effect for event type approached significance, F(1,23) = 4.13, p = 0.05, η² = 0.15, with the results demonstrating higher SCL for fake wins. Across event types there was a significant effect for B vs. PE1, F(1,23) = 11.72, p < 0.01, η² = 0.38. No significant effects for time were evident when comparing PE2, PE3 or PE4 to B for the SCL data. As depicted in Fig. 1, there were significant Event × Time interactions for SCL: for B vs. PE2, F(1,23) = 23.86, p < 0.001, η² = 0.51; and for B vs. PE3, F(1,23) = 15.52, p < 0.01, η² = 0.40. No significant effects were found when comparing PE1 or PE4 to B. The results indicate significant increases in SCL for fake wins (compared to losses) occurred between 5 and 8 seconds post-event (PE2) and that SCL values returned to baseline levels, 13–16 seconds post-event (PE4). For losses, SCL minimally decreased post-event before returning to baseline levels.

There was no significant main effect for event type for the HR data, but there was a significant effect for time, across event types, when comparing B to PE4, F(1,23) = 8.10, p < 0.05, η² = 0.26. Comparisons

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between baseline and PE1, PE2 and PE3 were not significant. No significant Event × Time interactions were observed for the HR data.

3.2.4. Baseline to peak values

Analyses showed that for SCL there was a significant effect for event type, \( F(1,23) = 11.41, p < 0.05, \eta^2_p = 0.70 \), with greater electrodermal activity to big wins than to small wins (Fig. 2). There was a significant Event × Time interaction for SCL between B and PE1, \( F(1,23) = 13.80, p < 0.01, \eta^2_p = 0.38 \). Comparisons between B and PE2, PE3, and PE4 were not significant. Both small wins and big wins were associated with post-event increases. The significant differences in electrodermal activity were most evident immediately following big wins compared to small wins, with big wins associated with greater immediate (1–4 seconds post-event) increases in SCL (Fig. 2).

There were no significant main or interaction effects for the HR data.

3.2.3. Small wins vs. big wins

Analyses showed that for SCRs there were significant differences in electrodermal activity to big wins than to small wins (Fig. 2). There was a significant Event × Time interaction for SCRs between B and PE1, \( F(1,23) = 11.54, p < 0.01, \eta^2_p = 0.33 \), followed by small wins (\( M = 0.55, SD = 0.44 \)), followed by small wins (\( M = 0.55, SD = 0.40 \)), fakes wins (\( M = 0.31, SD = 0.21 \)) and losses (\( M = 0.07, SD = 0.07 \)).

3.2.5. Stakes

The effects of the amount wagered or staking were analysed comparing the low and high stakes conditions. The data from the free stakes condition were excluded. Repeated measures ANOVA with three factors, Stake (low/high) × Event type (losses/fake wins/small wins/big wins) ×5 Time intervals (B, PE1, PE2, PE3 and PE4) were applied to the HR and SCL data separately. Planned within subjects contrasts (B vs. PE1; B vs. PE2, B vs. PE3 and B vs. PE4) were performed for the time factor, and 3 contrasts (small wins vs. losses, small wins vs. big wins, and losses vs. fake wins) were performed for the event type factor. Fig. 3 presents the SCL data at each of the time intervals.

The effects of Event type and Time have already been presented in the previous sections, therefore only main and interaction effects of the Stakes factor are considered. For SCL, the main effect of stakes was not significant; however, there was a trend for mean SCL to be consistently higher in the high stakes condition (Fig. 3). Interaction effects involving the stakes factor were not significant.

For the HR data, the main and interaction effects involving stakes were not significant.

3.3. Tonic responses before, during and after EGM play

Participants were given two-minute rest intervals before (baseline), between and after gambling sessions. Physiological data during these two-minute non-gambling periods are described as tonic measures. Repeated measures ANOVA for tonic HR and SCL were computed. Planned contrasts were performed to compare pre-experimental levels of HR and SCL to that recorded post-low, high and free stakes sessions. Fig. 4 shows that compared to baseline recordings, SCL was found to be greater in the two minutes following gambling at the low stakes, \( F(1,23) = 7.77, p < 0.05, \eta^2_p = 0.253 \); high stakes, \( F(1,23) = 11.54, p < 0.01, \eta^2_p = 0.334 \); and free stakes, \( F(1,23) = 7.87, p < 0.05, \eta^2_p = 0.255 \); conditions. A paired t-test was also computed to investigate the effect of gambling activity in general. For these analyses, a mean SCL was calculated for each participant’s during their first gambling session. SCL was found to significantly increase during the first gambling session (\( M = 12.08, SD = 3.93 \)) compared to the initial baseline recordings (\( M = 10.27, SD = 3.24 \)).

\( t(23) = 8.88, p < 0.001 \). In general, SCL increased significantly during
and following gambling sessions, with these increases being maintained but not enhanced or reduced by a change in staking conditions.

No significant differences were observed between the baseline and post-session tonic HR data; however, there was a trend for HR to reduce from pre-experiment baseline levels.

3.4. Relationship between physiological measures

Pearson correlations showed no significant associations between the tonic measures of HR and SCL data at each of the four data points. Moreover, tonic changes in HR and SCL for the three staking conditions were not significantly correlated to the amount won during the staking condition. Independent samples t-tests were computed comparing the tonic changes in HR and SCL pre- to post-the gambling conditions with winning a voucher during the conditions as an independent variable. There were no significant differences found in the tonic changes in HR or SCL for those that had won vouchers compared to those who had not during each staking condition.

For the phasic data, correlations between SCRs and HR changes (from baseline) served as dependent measures. Separate correlations were computed for wins and losses. Neither the phasic changes to wins, $r(24) = 0.03, p = 0.91$, or losses, $r(24) = -0.23, p = 0.28$, were significantly correlated.

3.5. Relationship between physiological responding to wins and losses

In order to examine whether physiological changes to wins matched changes to losses, SCRs to wins and losses and HR changes to wins and losses were correlated. A significant negative relationship was found for HR, $r(24) = -0.67, p < 0.001$ and SCRs, $r(24) = -0.48, p < 0.05$. The results indicate that higher responses to small wins correlated with lower responses to losses on the same physiological measure.

3.6. Relationship between physiological and self-report measures

The mean SOGS score of participants was 0.58 ($SD = 0.83$, range: 0–3), suggesting that the group comprised mostly non-problem
gamblers. As the range of scores was restricted, this variable was not analysed further. Scores on the IBS and GUS revealed no significant correlations with the tonic physiological data. Similarly, relative changes pre- to post-event types (as computed above for the phasic data) were not significantly related to any of the self-report measures for participants.

4. Discussion

The current study contributes in important ways to the existing literature on the psychophysiology of gambling. First of all, as far as the authors are aware, the study offers the first systematic and comprehensive analysis of psychophysiological changes during gambling on an electronic machine. Each of the four different event types, losses, fake wins, small wins and big wins, was examined. Cardiac and electrodermal activities were monitored and both tonic and phasic measures were obtained in high and low stake conditions. More importantly, the study demonstrates that physiological changes associated with rapidly occurring wins and losses during gambling on an electronic machine can indeed be measured reliably, and rapid changes captured on a second-by-second basis. This was achieved despite the confounds of multiple overlapping responses provoked by noisy bells, whistles, and visual displays, by using averaging procedures routinely employed by event-related potential experiments to enhance signal-to-noise ratios (see Picton et al., 2000). Importantly, although the study examined gambling in a non-clinical sample, the study paves the way for similar ambulatory studies to occur in the field to investigate psychophysiological differences that may characterise problem gamblers.

A key contribution of the study emanates from the use of multiple measures including electrodermal and cardiac activities. The findings were quite consistent in demonstrating the superiority of the SCL over HR to identify differences between win vs. loss events, fake wins vs. losses, big vs. small wins, and high vs. low stakes (trend). It is of note that these SCL differences were obtained even when participants gambled for small incentives and were not using their own money. These results corroborate the results of a pilot study on EGM play (Wilkes et al., 2009) and may indicate that SCL is more sensitive to subtle changes including those achieved in gambling analogue tasks (Goudriaan et al., 2006; Sharpe et al., 1995; Wilkes et al., 2009), whereas HR may be sensitive to larger changes observed when real money is wagered (e.g., Dickerson et al., 1992; Moodie and Finnigan, 2005). The lack of correspondence between the electrodermal and cardiac measures may also be the consequence of response fractionation and the possibility that HR indexes vigilance rather than arousal (Barry, 2006; Croft et al., 2004; VaezMousavi et al., 2007). Within such a context, the future inclusion of additional measures including respiration and finger-pulse volume is justified and may provide a greater insight into how the various physiological measures might complement each other.

The attention to loss events, neglected in previous EGM studies (e.g., Dickerson et al., 1992; Moodie and Finnigan, 2005) added value to the current study. Wins and losses produced SCRs that varied in magnitude and followed different temporal courses. Uniquely, the current study found significantly greater elevations of SCL to fake wins as compared to losses. Fake wins (1 of 5 trials) are a common characteristic of gambling on contemporary EGMs. It is possible that fake wins sustain interest in and contribute to the addictive nature of EGM play. These results also support the possibility that the inherent arousal in EGM gambling may be the primary reinforcer, with monetary gain serving as a secondary reinforcer (Wullert et al., 2005).

Also of note is the negative correlation observed between a person's responsivity to wins and losses. These results support the notion that individuals who are physiologically sensitive to rewards (wins) are also sensitive to losses (albeit by demonstrating a drop in SCL or HR). To the extent that SCRs and HR changes capture the individual's basic response to reward and punishment, these results are inconsistent with theories that posit that reward and punishment sensitivity are independent dimensions (e.g., Gray, 1987), but are consistent with the notion that individuals may vary in their reactivity to consequences (positive or negative). It will be of interest to determine the pattern and reactivity that characterises problem gamblers.

Gambling activity was associated with increases in SCL pre-to-post-session. This general increase was not dependent on winning or losing. The pattern of results obtained highlights the importance of monitoring both tonic and phasic changes observed within session in future research. In effect, win events (but not losses) produced identifiable and robust SCRs. In addition, significant SCL increases were observed following gambling tasks across winners and losers. In contrast, tonic HR decreased over the entire session. Because the random stakes condition always occurred last, progressively lower levels across sessions would be consistent with habituation effects. This pattern was not observed: SCL increased and HR decreased across the sessions.

4.1. Limitations and future directions

Ethical concerns precluded the participants from gambling with their own money. It could be argued that gambling for an entertainment voucher in a laboratory setting has limited ecological validity given that gambling in the field involves the possibility of significant wins and losses. However, it should be noted that despite these effects, significant SCL and SCR effects were identified; it is likely that these differences will be amplified when participants gamble with their own money (Ladouceur et al., 2003).

In the current experiment, the researchers did not alter the programming of the EGM. Hence, the 'bells and whistles' associated with these events occurred "naturally" as they would in the real world. Because wins, and particularly big wins, were very infrequent and are also associated with more stimulating visual and auditory stimuli, the larger SCRs to win amounts may reflect responses to the novelty, significance, complexity of accompanying stimuli (e.g., music and visual displays) rather than to the stimulus value (Ben-Shakhar, 1994; Gati and Ben-Shakhar, 1990; Sokolov, 1963). Although the current study cannot rule out the possibility that novelty and accompanying visual and sound cues to win stimuli contributed to the physiological changes, it is likely that the value of winning or losing also played a role. For instance, equally novel win events tended to produce larger responses in the high stakes as compared to the low stakes condition. Also, data from a follow-up study in our laboratory using a computer-based program without the bells and whistles have replicated these results when novelty (frequency) was controlled. In any event, it was important to establish the pattern of physiological activity associated with wins and losses in an ecologically valid context (bells and whistles included) before further analyses of the sources of these effects could be determined.

A comparison of problem gamblers and normal controls will be an important focus for future study and is currently underway. It will be of value to determine if problem gamblers are characterised by unique physiological patterns in the way they respond to wins and losses dispensed by electronic machines.

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