Severity of gambling problems modulates autonomic reactions to near outcomes in gambling

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Abstract

Outcomes in gambling games cannot only be classified based on their valence (wins and misses) but also based on their closeness (near and full outcomes). The present study investigated autonomic responses (phasic heart period changes and skin conductance responses) to near and full outcomes on a wheel of fortune in a sample of males with different degrees of gambling problems. Near relative to full outcomes elicited increased interbeat intervals shortly after outcome presentation. Furthermore, participants with more severe gambling problems showed increased skin conductance responses following near relative to full outcomes as well as relatively smaller interbeat interval responses to near relative to full misses. The findings confirm different processing of near compared to full outcomes and altered processing of gambling outcomes with increasing severity of gambling problems.

Keywords: gambling, near miss, narrow win, problem gambling, electrodermal activity, heart rate
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Near misses are miss outcomes that are close to a win (Reid, 1986). Previous research has shown that compared to full misses, near misses are rated as being closer to a win, and are more motivating but less satisfying (Clark, Lawrence, Astley-Jones, & Gray, 2009; Dixon & Schreiber, 2004). In a recent study we introduced narrow wins, i.e. the win counterpart of near misses, which may be defined as win outcomes that are close to a miss (Ulrich & Hewig, 2014).

Previous studies have shown that near misses are processed differently by participants with and without gambling problems. Chase and Clark (2010) showed that participants with higher scores on a screening questionnaire for problem gambling showed more activation in the midbrain to near misses than to full misses. Habib and Dixon (2010) showed that participants with more gambling problems showed more activation in win-related brain regions following near misses, whereas participants with few to no gambling problems showed more activation in loss-related brain regions. Dymond et al. (2014) found that near misses compared to full misses were followed by greater theta power increases in the MEG in several frontal and insular areas. Theta power changes in the right orbitofrontal cortex following near misses were positively correlated with gambling problems.

So far, no study has investigated the processing of narrow wins in problem or pathological gamblers, although some gambling games also include the possibility of winning narrowly (e.g. Black Jack; a player wins narrowly when his card value is one point higher than the card value of the dealer). However, some studies have examined related questions. Narrow wins represent outcomes that barely resulted in a positive outcome. As such, gambling trials resulting in narrow wins are related to risky choices with positive outcomes. Studies have shown that pathological gamblers react especially favorably to positive outcomes of a risky choice, as indexed by an increased reward positivity in the event-related potential of the EEG (Hewig et al., 2010; Oberg et al., 2011).
Several studies have looked at physiological responses during gambling in pathological and problem gamblers. Most of these studies examined tonic physiological measures (e.g. skin conductance level, heart rate) for the entire period of gambling (e.g. Anderson & Brown, 1984; Carroll & Huxley, 1994; Diskin, Hodgins, & Skitch, 2003; Meyer et al., 2000; Meyer et al., 2004; Moodie & Finnigan, 2005). The results generally point towards increased physiological arousal during gambling compared to baseline, with some studies (e.g. Moodie & Finnigan, 2005; Meyer et al., 2004) pointing towards differences in arousal between different types of gamblers (e.g. problem and nonproblem gamblers; frequent and infrequent gamblers), with problem or frequent gamblers showing more arousal while gambling. Studies analyzing phasic physiological responses to discrete gambling outcomes are scarcer. Wilkes, Gonsalvez, and Blaszczynski (2010) showed that it is possible to measure phasic skin conductance and heart rate responses to outcomes on electronic gaming machines. They showed that wins compared to losses were followed by increased skin conductance responses in healthy subjects. In a later study, Lole, Gonsalvez, Barry, and Blaszczynski (2014) analyzed skin conductance in problem and nonproblem gamblers while they were playing on electronic gaming machines. They found that nonproblem gamblers showed increased skin conductance responses for wins compared to misses, whereas problem gamblers showed similar responses to both outcomes. Several other studies have investigated phasic skin conductance and heart rate responses following near misses. Most studies found signs of increased phasic physiological arousal, indicated by increased skin conductance responses following near compared to full misses (Clark, Crooks, Clarke, Aitken, & Dunn, 2012; Clark et al., 2013; Dixon et al., 2011; Dixon, MacLaren, Jarick, Fugelsang, & Harrigan, 2013), whereas Lole, Gonsalvez, Blaszczynski, and Clarke (2012) found no significant differences between the two miss outcomes. Concerning heart rate and heart period changes, the results are more mixed, though. Clark et al. (2012) and Clark et al. (2013) report a biphasic heart rate response.
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following the outcomes, with an initial decrease of the heart rate followed by a subsequent 
increase. In both studies, there were no differences in the initial decrease of the heart rate. 
Clark et al. (2012) found larger subsequent heart rate increases for near misses compared to 
both wins and full misses. Clark et al. (2013) reported slightly different results for the 
subsequent heart rate increase, with near misses showing a larger heart rate increase than 
wins, but no significant difference to full misses. Furthermore, the heart rate increase 
following near misses significantly predicted persistence in the gambling task, with smaller 
heart rate increases after near misses leading to increased persistence. Dixon et al. (2011) 
reported larger heart period increases (corresponding to heart rate decreases) for near 
compared to full misses. Based on the timing of the paradigm used by Dixon et al. (2011), the 
observed heart period increases might have been the first part of a biphasic heart rate 
response. Finally, Lole et al. (2012) found no differences between near and full misses in the 
elicted heart rate responses. Thus, while the skin conductance results point towards increased 
physiological arousal following near misses, the heart rate results are more mixed, with one 
study (Clark et al., 2012) showing greater subsequent heart rate increases, one study showing 
greater initial heart rate decreases in a biphasic heart rate response (Dixon et al., 2011) and 
two studies (Clark et al., 2013; Lole et al., 2012) finding no difference between near and full 
misses in the elicited heart rate responses. Three of the previously mentioned studies also 
investigated whether the amount of pathology in the gambling behavior correlates with 
physiological responses to near miss outcomes but did not find evidence for a relation (Clark 
et al., 2012; Dixon et al., 2011; Dixon et al., 2013). The sample used in Clark et al. (2012) 
consisted of students and thus included only three subjects scoring in the problem gambling 
range of the South Oaks Gambling Screen (SOGS; score > 2), with the rest scoring below the 
problem gambling range. Hence, a potential relation between gambling status and 
physiological responses to near misses might have been masked by the specific sample used.
In the current study, we wanted to further elucidate physiological responses to near and full outcomes and their potential relation to differences in gambling pathology. Thus, we recruited participants with a range of scores on gambling screening questionnaires and let them play on a wheel of fortune while skin conductance and heart period were measured. We hypothesized that near outcomes of either type, as compared to the respective full outcomes, would lead to increased physiological responses, visible as greater skin conductance response amplitudes and an increased biphasic heart period response. Since previous studies on near misses have shown mixed results concerning whether the effect occurs in the initial heart period increase or subsequent heart period decrease, we did not have a specific hypothesis as to which component of the biphasic heart period response would show an effect. Based on the literature, it is conceivable that either the initial heart period increase, the subsequent heart period decrease or both components are more pronounced following near compared to full outcomes. Finally, we expected greater skin conductance response amplitudes and increased biphasic heart period responses (stronger initial heart period increase and/or stronger subsequent heart period decrease) to near outcomes in participants scoring higher on problem gambling screening scales.

Methods

Participants

50 male participants were included in the current study. We focused on males only, since gambling problems show a higher prevalence for males than for females (Bundeszentrale für gesundheitliche Aufklärung (Federal Centre for Health Education), 2014; Erbas & Buchner, 2012). First, a pool of potential participants was recruited via advertisement in the job section of a local website. Applicants filled in an online questionnaire consisting of demographic questions (age, gender, handedness, education) and two screening instruments for pathological gambling (Kurzfragebogen zum Glücksspielverhalten, KFG, Petry, 1996;
South Oaks Gambling Screen, SOGS, Lesieur & Blume, 1987). We aimed at including participants from a broader range of scores on the gambling screens in our final sample. Thus, we used the pool of potential participants to recruit about half of the final sample from people below and above the cutoff scores for pathological gambling in the screenings respectively (cutoff SOGS = 5, cutoff KFG = 16)\(^1\). The final sample consisted of 50 participants (mean age = 27.78, SD = 9.12, Range: 18-56), 20 of whom had SOGS scores of 5 or greater and 21 of whom had scores of 16 or greater on the KFG. The mean score for SOGS was 3.82 (SD = 3.10), the mean score for KFG was 13.38 (SD = 8.05); correlation coefficient was \(r = 0.652\). Further information on the number of regular gamblers and their favorite forms of gambling can be found in Table 1. Participants were paid 10 Euros for participation and received an extra 2 Euros for their performance in the wheel of fortune. The study was approved by the local ethics commission.

\(^1\) Regular gambling was no inclusion criterion. The main focus in the recruiting process was to achieve a broad distribution of scores in the gambling screenings in the final sample of 50 participants. Thus, especially the participants in the lower range of scores on the gambling screenings also include non-regular gamblers.
Table 1. Number of regular and non-regular gamblers and regular gamblers’ favorite games.

<table>
<thead>
<tr>
<th></th>
<th>n Regular Gamblers</th>
<th>n Non-Regular Gamblers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Card Games</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Sports Bet</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Casino</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Lotteries</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Stock Market</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Slot Machines</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Play Games of Skill for Money</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Online Gambling</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Notes: The number of regular gamblers was derived from the SOGS. Every participant who reported pursuing at least one gambling game at least once per week was counted as regular gambler. The favorite games were also derived from the SOGS and for each game gives the number of participants playing the respective game at least once per week.

Paradigm: Wheel of Fortune

The wheel of fortune used in this study was similar to the one used in our EEG-study (Ulrich & Hewig, 2014). In every trial, participants had to place a bet on one of the two colors on the wheel of fortune. The wheel consisted of eight segments spanning 45° each, alternately colored orange and turquoise. At the beginning of each trial, the wheel spun at a constant speed. The spinning motion was created by displaying a series of pictures in rapid succession, thus creating the impression of a counter-clockwise motion of the wheel. 72 pictures were used, each showing a 5° change of the position of the wheel, relative to the previous picture. Each picture was displayed for 16.7 ms, corresponding to the 60Hz refresh rate of the screen.
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The wheel continued spinning until participants placed a fixed bet of 40 Cents on one of the colors. Following a variable (2.1-2.4 seconds) phase of spinning at the same speed as before, the wheel then gradually decelerated to a standstill. The phase of gradual deceleration always lasted for 4.5 seconds. Together with a variable phase of spinning at the previous speed, this made the phase between color choice and outcome presentation 6.8 seconds long on average (range: 6.6-6.9 seconds). Upon standstill, the outcome of the current trial was presented for 4 seconds. During the following variable intertrial interval (6-8 seconds, equally distributed), the running total was displayed. Figure 1 presents the time course of a sample trial.

Figure 1. Sample trial of the wheel of fortune paradigm.

Every participant started with an endowment of 200 virtual Cents. The participants were instructed that a running total of at least 320 Cents at the end of the game would result in a bonus payment of 2 Euros. The gambling game started with three practice runs after which the virtual account was reset to 200 Cents. The main block of the study consisted of 80 trials with 20 trials in each of the following conditions: full wins, narrow wins, full misses and near misses (see Figure 2 for examples of the different outcome types). On win trials, participants won 40 Cents, while the 40 Cent bet was lost on miss trials.
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Figure 2. Examples of the four different outcome types.

The sequence of the outcomes was pseudo-randomized for every participant. The final eight trials (81-88) were the same for every participant and ensured that the game ended with a running total of 360 Cents, thus entitling every participant for the 2.00 € bonus payment.

Heart period and skin conductance measurement

Heart period and skin conductance were recorded with a sampling rate of 250Hz using a BrainVision BrainAmp ExG amplifier (Brain Products GmbH, Gilching, Germany) and the BrainVision Recorder 1.20 software (Brain Products GmbH). Heart period was measured using three disposable Ag/AgCl electrodes (Kendall ECG Electrodes H98LG, Covidien, Neustadt, Germany) placed according to a modified Einthoven II lead. The ground electrode was placed below the left collarbone, the negative electrode below the right collarbone, and the positive electrode on the left side below the rib cage. Skin conductance was measured via two Ag/AgCl electrodes (diameter of conductive contact area : 7 mm) placed on the fingertip of the left index finger and middle finger respectively. The electrodes were filled with TD-246...
Skin Conductance Electrode Paste (0.5 % saline in neutral base, Discount Disposables, St. Albans, Vermont).

Procedure

Upon entering the lab, participants first received written information about the experiment and filled in an informed consent form. Next, the electrodes for measuring heart period and skin conductance were attached. Participants then started gambling on the wheel of fortune. After completion, electrodes were detached and participants filled in additional questionnaires.

Questionnaires

The questionnaires included a sheet of follow-up questions concerning the wheel of fortune task, the Gambling Related Cognitions Scale (GRCS, Raylu & Oei, 2004), the UPPS-Impulsivity Scale (UPPS, Keye, Wilhelm, & Oberauer, 2009; Whiteside & Lynam, 2001) and the DOSPERT Risk Taking and Risk Perception Scales (Johnson, Wilke, & Weber, 2004).

The follow-up questions asked for strategies used in the wheel of fortune gamble, whether bets were placed on a favorite color, whether participants had previously taken part in a similar experiment, what they thought the experiment was about, and whether they noticed that there were near outcomes. Except for the follow-up questions, no further results from the questionnaires will be reported here.

Heart period analysis

For the analysis of the phasic heart period response, we first detected the peaks of the R-waves using QRS-Tools software (Allen, Chambers, & Towers, 2007). During this step, all IBI-series were inspected visually and corrected for ectopic beats, where necessary. Twelve participants showed ectopic beats in their IBI data, all of them followed by a compensatory pause\(^2\). The correction consisted of removing the marker on the ectopic beat and then inserting a marker in the middle of the resulting longer IBI. Mean event-related interbeat

\(^2\) All of these participants showed very few ectopic beats, hence none of them was excluded.
intervals (IBIs) were computed for every participant and outcome type using a custom-built Matlab script. This script extracted the length of the IBI during which the outcome onset occurred (in the following denoted as “IBI around”) as well as the length of the six IBIs prior and following outcome onset (labeled “IBI-6” to “IBI-1” and “IBI+1” to “IBI+6”, respectively). Incorporating the results of previous studies with respect to biphasic heart period responses, a single measure of IBI response was calculated and correlated with scores on the KFG. This single IBI reaction measure was computed as follows: first, the minimum heart period before and after outcome onset was detected. Then, the maximum heart period in between the two detected minima was determined. The IBI reaction measure was then calculated as the average of the following differences: maximum - minimum before and maximum - minimum after. Thus, this measure quantifies the average IBI change for a given outcome. It was extracted on a single trial basis for every participant and then averaged across trials for every outcome type.

Skin conductance response analysis

Skin conductance data were processed using custom-built Matlab scripts. The data were filtered with a 5th order 2.5 Hz lowpass Butterworth filter and a 5th order 0.05 Hz highpass Butterworth filter (Figner & Murphy, 2011). For every outcome, the amplitude of the skin conductance response (SCR) was assessed as the largest difference between a local minimum and a subsequent local maximum in the time window from 0 to 5 seconds following outcome onset. We chose a different time window compared to the commonly used 1-3 or 1-4 seconds poststimulus (Dawson, Schell, & Filion, 2007), as our paradigm involves a deceleration phase of the wheel of fortune. It is thus conceivable that some participants realize their outcomes earlier than others, thus we chose a broad time window starting with outcome onset to detect all SCRs elicited by the outcomes. The SCR magnitudes were transformed 3

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3 If there was no local minimum present in this time window, SCR was scored as the difference between the global maximum in the time window minus the skin conductance value at time 0. If there was no local maximum present or there was no local minimum followed by a local maximum, SCR was scored as 0.
using the natural logarithm (ln) of x+1 with x being the measured SCR value in microsiemens (Dawson et al., 2007). For every participant, the ln(x+1)SCR values were averaged across trials for each outcome type.

Statistical Analysis

The IBI around outcome onset and the six IBIs following outcome onset were analyzed in a 7x2x2 repeated measures ANOVA with the factors “IBI number” (IBI around vs. IBI+1 vs. IBI+2 vs. IBI+3 vs. IBI+4 vs. IBI+5 vs. IBI+6), “outcome” (win vs. miss) and “closeness” (full vs. near). Where necessary, p-values were Greenhouse-Geisser corrected. Post-hoc t-tests with p-values adjusted to a false discovery rate of 0.05 (Benjamini & Hochberg, 1995) were used to analyze significant interactions. The SCR was analyzed in a 2x2 repeated measures ANOVA with the factors “outcome” (win vs. miss) and “closeness” (full vs. near). To assess the relation between gambling status and physiological responses to outcomes in the wheel of fortune, we computed ANCOVAs with the factors “outcome” (win vs. miss) and “closeness” (full vs. near) and included z-standardized KFG-scores as the covariate. The dependent variables used in the two ANCOVAs were mean IBI increase around outcome onset and SCR, respectively. Except for the ANCOVAs, all statistical analyses were run in R 3.1.2 (R Core Team, 2014). The ANCOVAs were run in SPSS 21.

Results

Heart period

The time course of the event-related IBIs is depicted in Figure 3, the results of the ANOVA are included in Table 2. As the time course shows, a biphasic response is discernible, with an initial increase of the heart period around outcome onset and a subsequent heart period decrease. The analysis of the IBIs around and following outcome onset revealed significant main effects of “outcome” ($F(1,49) = 11.19, p = .002, \eta^2_p = .19$), and “IBI number”
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\( F(6,294) = 88.88 \ p < .001, \eta^2_p = .64 \), as well as a significant interaction of “IBI number” and “closeness” \( F(6,294) = 4.55 \ p < .001, \eta^2_p = .08 \). Follow up t-tests with adjusted p-values according to Benjamini & Hochberg (1995) showed that full and near outcomes differed significantly at IBI+1 \( t(49) = 3.39 \ p = .010 \) and IBI+2 \( t(49) = 2.72 \ p = .032 \) with near outcomes showing larger IBIs.

**Table 2.** Results of the ANOVAs for the dependent measures IBI and SCR.

<table>
<thead>
<tr>
<th>Dependent Variable &amp; Effects</th>
<th>F (df)</th>
<th>p</th>
<th>\eta^2_p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IBI</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“outcome”</td>
<td>11.19 (1, 49)</td>
<td>.002</td>
<td>.19</td>
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<tr>
<td>“closeness”</td>
<td>3.13 (1, 49)</td>
<td>.083</td>
<td>.06</td>
</tr>
<tr>
<td>“IBI number”</td>
<td>88.88 (6, 294)</td>
<td>&lt;.001</td>
<td>.64</td>
</tr>
<tr>
<td>“outcome” x “closeness”</td>
<td>0.20 (1, 49)</td>
<td>.657</td>
<td>&lt;.01</td>
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<tr>
<td>“outcome” x “IBI number”</td>
<td>0.95 (6, 294)</td>
<td>.399</td>
<td>.02</td>
</tr>
<tr>
<td>“closeness” x “IBI number”</td>
<td>4.55 (6, 294)</td>
<td>.004</td>
<td>.08</td>
</tr>
<tr>
<td>“outcome” x “closeness” x “IBI number”</td>
<td>1.17 (6, 294)</td>
<td>.324</td>
<td>.02</td>
</tr>
<tr>
<td><strong>SCR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“outcome”</td>
<td>0.18 (1, 49)</td>
<td>.671</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>“closeness”</td>
<td>0.22 (1, 49)</td>
<td>.641</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>“outcome” x “closeness”</td>
<td>3.44 (1, 49)</td>
<td>.070</td>
<td>.07</td>
</tr>
</tbody>
</table>
Figure 3. Mean event-related IBIs relative to outcome onset. The x-axis reflects the number of the IBI relative to the IBI around outcome-onset.

Skin conductance

The results of the ANOVA with SCR as the dependent variable are also included in Table 2. The analysis of the skin conductance data showed no significant effects, only a marginally significant interaction of “outcome” and “closeness” ($F(1,49) = 3.44, p = .070, \eta^2_p = .07$). At a descriptive level, near misses ($M = 0.046$) visually appeared as eliciting larger SCRs than full misses ($M = 0.040$), whereas narrow wins ($M = 0.040$) visually appeared as
eliciting smaller SCRs than full wins ($M = 0.043$)\textsuperscript{4}. However, these differences were nonsignificant.

Relations with gambling status

The results of the ANCOVAs for IBI reaction and SCR are depicted in Table 3. For mean IBI reaction there was a significant three-way interaction between “outcome”, “closeness”, and KFG ($F(1,48) = 4.20$ $p = .046$, $\eta^{2}_p = .08$), a marginal main effect of the covariate KFG ($F(1,48) = 3.28$ $p = .077$, $\eta^{2}_p = .06$), and a marginal interaction between “outcome” and KFG ($F(1,48) = 3.68$ $p = .061$, $\eta^{2}_p = .07$). To further analyze the significant three way interaction, we computed scores to quantify the effect of closeness separately for wins and misses and to quantify the effect of outcome separately for full and near outcomes. Specifically, we subtracted the mean IBI reaction following full outcomes from the mean IBI reaction following near outcomes for wins and misses separately and we subtracted the mean IBI reaction following miss outcomes from the mean IBI reaction following win outcomes for full and near outcomes separately. We then correlated each of the four difference measures with the KFG score; p-values were adjusted according to Benjamini & Hochberg (1995).

Figure 4 depicts the four respective scatterplots. There were significant correlations between the closeness effect for misses and the KFG ($r = -.352$ $p = .024$) as well as the outcome effect for full outcomes and the KFG ($r = -.361$ $p = .024$). Participants with higher KFG scores showed decreased differences between near and full misses. As the scatterplot (see Figure 4A) indicates, this difference becomes negative for participants with higher KFG scores, indicating that they show a smaller IBI reaction to near compared to full misses. Regarding the correlation with the outcome effect for full outcomes, participants with higher KFG scores showed a decreased difference between full wins and misses. The scatterplot (see Figure 4C) shows that this difference also becomes negative for participants with high KFG scores,

\textsuperscript{4} The raw SCR means for the different outcome types are: full wins = 0.048; full misses = 0.046; narrow wins = 0.044; near misses = 0.052.
indicating that they show a smaller IBI response to full wins compared to full misses. Figure 5 shows the pattern of IBI responses for participants scoring low (z-score <= -1) and high (z-score >= 1) on the KFG. As can be seen, participants scoring low on the KFG show the strongest IBI response to full wins, whereas participants scoring high on the KFG show the strongest response to full misses.

The ANCOVA with SCR as dependent variable yielded a significant interaction of “closeness” and KFG ($F(1,48) = 4.43, p = .041, \eta^2_p = .09$), as well as a marginally significant interaction between “outcome” and “closeness” ($F(1,48) = 3.48, p = .068, \eta^2_p = .07$). As Figure 6 shows, there is a positive linear correlation between KFG scores and the difference in SCR between near and full outcomes ($r = .29, p = .041$), with participants with higher KFG scores showing increased SCR responses to near vs. full outcomes.
**Table 3: Results of the ANCOVAs for the dependent measures mean IBI reaction and SCR**

<table>
<thead>
<tr>
<th>Dependent Variable &amp; Effects</th>
<th>$F$ (df)</th>
<th>$p$</th>
<th>$\eta^2_p$</th>
</tr>
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<tbody>
<tr>
<td><strong>mean IBI reaction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“outcome”</td>
<td>0.21 (1, 48)</td>
<td>.649</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>“closeness”</td>
<td>0.436 (1, 48)</td>
<td>.512</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>KFG (covariate)</td>
<td>3.28 (1, 48)</td>
<td>.077</td>
<td>.06</td>
</tr>
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<td>“outcome” x “closeness”</td>
<td>0.76 (1, 48)</td>
<td>.389</td>
<td>.02</td>
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<tr>
<td>“outcome” x KFG</td>
<td>3.68 (1, 48)</td>
<td>.061</td>
<td>.07</td>
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<tr>
<td>“closeness” x KFG</td>
<td>1.33 (1, 48)</td>
<td>.254</td>
<td>.03</td>
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<td>.046</td>
<td>.08</td>
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<td><strong>SCR</strong></td>
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</tr>
<tr>
<td>“outcome”</td>
<td>0.18 (1, 48)</td>
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<td>&lt;.01</td>
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<tr>
<td>“closeness”</td>
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<td>&lt;.01</td>
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<tr>
<td>KFG (covariate)</td>
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<td>.04</td>
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<td>“outcome” x “closeness”</td>
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<td>.226</td>
<td>.03</td>
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</table>
Figure 4. Scatterplots of the KFG z-scores and differences measures for outcome and closeness effects; A) mean IBI reaction response to near misses minus full misses; B) mean IBI reaction to narrow wins minus full wins; C) mean IBI reaction to full wins minus full misses; D) mean IBI reaction to narrow wins minus near misses.
Figure 5. Mean IBI responses for full wins, near wins, full misses and near misses for participants with a z-score KFG <= -1 (n = 10) and a z-score KFG >= 1 (n = 8), illustrating the interaction of Outcome, Closeness and KFG in the ANCOVA. Error bars denote standard errors of the mean adjusted for within-subject designs according to Cousineau (2005) and Morey (2008).

Figure 6. Relation between KFG z-scores and the closeness effect in SCR. The closeness effect was computed as the mean SCR to near outcomes minus the mean SCR to full outcomes; hence, positive values denote a greater mean SCR to near than to full outcomes.

Perception of closeness

Three participants reported not having recognized that some of the outcomes were close while others were not. Excluding these participants from the analysis did not
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qualitatively change results, except for the main effect of the covariate KFG in the IBI response analysis, which then was significant ($F(1,45) = 4.27 \ p = .045, \eta^2_p = .09$). With higher KFG scores, participants showed less overall IBI response to the outcomes ($r = -.29$).

Discussion

The present study aimed to reveal physiological response patterns in gamblers with different degrees of gambling problems in a gambling task including near and full monetary wins and losses. We were particularly interested in phasic heart period and electrodermal responses, their modulation by the four different outcomes, and the possible influence of problem gambling as reflected in respective scales.

Heart Period

The analysis of the event related heart period showed a main effect of outcome, as well as a significant interaction of IBI number and closeness. Misses compared to wins were followed by longer IBIs. Similar results have been reported in previous research, where negative feedback (Crone et al., 2003; Mueller, Stemmler, & Wacker, 2010; Somsen, van der Molen, Jennings, & van Beek, 2000) or errors (Hajcak, McDonald, & Simons, 2003) also elicited a relative deceleration of the heart rate compared to wins. This deceleration has been interpreted similarly to the Error Related Negativity (ERN) and Feedback Related Negativity (FRN) (Somsen et al., 2000), two event-related potentials in the EEG that occur after errors and negative feedback (Gehring, Coles, Meyer, & Donchin, 1990; Gehring & Willoughby, 2002; Miltner, Braun, & Coles, 1997). The FRN has been interpreted in terms of indicating a reward prediction error (Holroyd & Coles, 2002), that is a mismatch between an actual and an expected outcome, and also in terms of indicating more negative valence of the eliciting stimulus (Hajihosseini & Holroyd, 2013; Sambrook & Goslin, 2015). Furthermore, the ERN and FRN are generated in the anterior cingulate cortex (ACC) (Dehaene, Posner, & Tucker, 1994; Luu, Tucker, Derryberry, Reed, & Poulson, 2003; Miltner et al., 1997), a structure that
has also been shown to be involved in cardiac regulation (Critchley, Corfield, Chandler, Mathias, & Dolan, 2000; Gianaros, van der Veen, & Jennings, 2004). This is another hint at a common underlying error detection process (but see also results showing no correlation between the ERN and cardiac error-related deceleration (Hajcak et al., 2003), suggesting that central nervous and autonomic parameters may reflect different aspects of the error processing.)

In accordance with our hypothesis, near compared to full outcomes lead to longer IBIs, but only for the first two IBIs following the outcome. This result indicates a prolonged heart period increase for near outcomes, and is thus more similar to the result reported by Dixon et al. (2011), who found larger heart period increases for near compared to full misses, than to the results reported by Clark et al. (2012), who found increased subsequent heart rate acceleration for near compared to full misses. There was no interaction with the factor outcome, suggesting that this pattern is the same for both wins and misses. As such, this result resembles previous findings in the wheel of fortune using EEG and event related potentials. Near compared to full outcomes generally elicited a more negative FRN and a smaller P300 (Ulrich & Hewig, 2014). In keeping with the above FRN-analogue interpretation of event-related heart period increase, the larger increase following near outcomes could indicate a more negative evaluation of those outcomes or a stronger violation of expectations. Just before receiving a near outcome, the participant might already expect the opposite outcome (e.g. when the wheel is in a field of the chosen color but approaching the boundary to the other color). This expectation is then violated when the near outcome is presented. However, a more processing oriented interpretation of the findings is also conceivable. According to Lacey (1967), an IBI increase following a stimulus suggests increased perceptual processing of that stimulus. Applying this interpretation to the current results suggests that near outcomes could have been processed more deeply. Given the appearance of near outcomes with the pointer stopping close to the boundary of the color fields, it makes intuitive sense that
participants need to process the stimulus more deeply to determine on which side of the boundary the pointer actually stopped. Based on the current data, we cannot draw final conclusions on which of the explanations is correct. The perceptual processing and FRN-analogue explanations could specifically be tested in a paradigm employing stimuli with less physical difference between near and full outcomes, e.g. a game based purely on numbers. In this case, all outcomes should require the same amount of perceptual processing.

It is also notable that the biphasic heart period response was shifted in time, relative to some previous studies (Clark et al., 2012; Clark et al. 2013), with the peak of the heart period increase occurring at outcome onset and not after outcome onset. A similar result of heart rate changes starting before the outcome presentation has been reported by Dixon et al. (2011). In the wheel of fortune paradigm used in the current study, the shift in the heart period response is likely caused by the anticipation phase, involving the gradual slowing of the wheel of fortune, starting 4.5 seconds before outcome presentation. As the length of this time period did not change within the experiment, participants could learn when to expect the outcome. This pattern also resembles anticipatory heart rate decelerations reported for speeded response tasks (for a review, see Jennings & van der Molen, 2005). Following the suggestion of Lacey (1967), the increase of heart period during the anticipation phase could also indicate the recruitment of processing resources as a preparation for processing the subsequent outcome.

**Skin conductance**

Contrary to our hypothesis, we did not find any significant effects of outcome types on the SCRs. As such, we did not replicate previous studies which have shown increased SCRs following near misses compared to full misses (Clark et al., 2012) or even compared to full wins (Dixon et al., 2011). Generally, the SCRs elicited by our paradigm were relatively small. Furthermore, compared to previous studies, we used different outcome probabilities. While Clark et al. (2012) and Dixon et al. (2011) used paradigms in which near misses were less frequent than full misses (and also less frequent than wins in Dixon et al., 2011), our
paradigm delivered all four outcome types evenly across the experiment. It has been shown that stimulus probability influences the SCR, with less frequently occurring stimuli eliciting larger SCRs (Ben-Shakhar, Lieblich, & Kugelmass, 1982).

**Correlation with gambling questionnaires**

The ANCOVA analyses of IBI reaction and SCR revealed significant influences of the KFG on both physiological parameters. For IBI reaction, a three-way interaction was present, indicating that with increased KFG scores both the difference between near and full misses, as well as the difference between full wins and full misses changed. Participants with low scores on the KFG showed increased IBI reactions to near compared to full misses and to full wins compared to full misses. This pattern changes as scores on the KFG increase. Participants with high KFG scores showed increased IBI reactions to full misses, both compared to near misses and full wins. The latter difference reflects patterns found in previous research, showing problem gamblers to react less to wins in gambling (Lole et al., 2014). For SCR, there was an interaction between the covariate and the “closeness” factor. Participants with higher scores on the KFG showed increased SCRs to near compared to full outcomes. Thus, our hypothesis of increased effects of the “closeness” factor with increased gambling problems was only partly supported. SCRs showed the expected pattern of results. For IBI responses, the pattern was reversed, though and specific for near compared to full misses, and did not apply to near outcomes in general.

The diverging results for the cardiac and the electrodermal measure point towards possible differences in the autonomic system associated with gambling problems: short-term heart period reactions are supposed to be mainly influenced by parasympathetic activity (Berntson et al., 1997; Berntson, Quigley, & Lozano, 2007), while SCRs are more likely influenced by sympathetic activity (Dawson et al., 2007). Previous studies on activity of the sympathetic nervous system in problem and pathological gamblers have yielded mixed results, with some studies finding no sympathetic alterations (Labudda, Wolf, Markowitsch,
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& Brand, 2007) and others finding increased sympathetic activation in problem gamblers (Krueger, Schedlowski, & Meyer, 2005; Meyer et al., 2004). While the current study was not designed to specifically address the activity of the sympathetic and parasympathetic system in problem gamblers, future studies could address this question.

In summary, it might be suggested that problem gamblers show increased arousal (SCR) to all near as compared to full outcomes and a more negatively valenced vagal physiological response (IBI reaction) to full misses only. Based on the assumption that participants have a composite subjective experience of their physiological responses, suggests that full losses elicit a specifically negative (FRN interpretation of IBI) and low arousal experience (no SCR) in PGs, which sets those events apart. In contrast to those events, problem gamblers show indistinguishable responses to all kinds of near outcomes and finally a possibly reduced arousal (lower SCR) to full wins. This would be in line with the previously shown role of near misses which is in stark contrast to the processing of and response to full misses.

Limitations

Some limitations should be kept in mind when interpreting the study results. We did not measure breathing of the participants. Thus, we cannot rule out that part of the variance in the heart period measure is related to participants’ breathing. In addition, we did not control for variables such as smoking, caffeine consumption and time of day, which might have influenced autonomic activity between participants and thus led to unsystematic variance. We also did not assess comorbidities or treatment-seeking in our sample, preventing us from taking these variables into account in the analyses. Furthermore, the fluctuation of the running total was random for each participant, since only the total number of each outcome type was predetermined, but not their sequence. The running total might serve as a context in light of which the outcomes are interpreted and thus the same outcome combined with a different
running total could evoke different physiological responses. This could have created additional error variance in our study.

**Summary**

We showed that near and full wins and misses differ in their elicited heart period reactions. Misses are followed by generally longer IBIs, whereas after near compared to full outcomes only the first two IBIs are longer. Furthermore, IBI reactivity and SCR following outcomes were moderated by scores on the KFG. Participants with higher scores on the KFG showed a smaller difference in IBI reactivity to near compared to full misses as well as an increased difference in SCR to near compared to full outcomes in general. The IBI responses in participants with high KFG scores suggest near outcomes elicit a win-like response, while the response to full misses differs from that to other outcomes.
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