7-2019

Behavioral and Psychophysiological Effects of Near-Miss Outcomes in a Game of War

Erin Wylie
ewylie@nmu.edu

BEHAVIORAL AND PSYCHOPHYSIOLOGICAL EFFECTS OF NEAR-MISS OUTCOMES IN A GAME OF WAR

By

Erin Elizabeth Wylie

THESIS

Submitted to
Northern Michigan University
In partial fulfillment of the requirements
For the degree of

MASTER OF SCIENCE

Office of Graduate Education and Research

July 2019

SIGNATURE APPROVAL FORM

BEHAVIORAL AND PSYCHOPHYSIOLOGICAL EFFECTS OF NEAR-MISS OUTCOMES IN A GAME OF WAR

This thesis by Erin Elizabeth Wylie is recommended for approval by the student's Thesis Committee and Department Head in the Department of Psychological Science and by the Dean of Graduate Education and Research.

_____

Committee Chair: Dr. Jacob Daar Date

_____

First Reader: Dr. Joshua Carlson Date

_____

Second Reader: Dr. Seth Whiting Date

_____

Department Head: Dr. Adam Prus Date

_____

Dr. Lisa Schade Eckert Date
Dean of Graduate Education and Research

ABSTRACT

BEHAVIORAL AND PSYCHOPHYSIOLOGICAL EFFECTS OF NEAR-MISS OUTCOMES IN A GAME OF WAR

By

Erin Elizabeth Wylie

Within the gambling literature, the misidentification of outcomes has been shown to affect gambling behaviors in players. A notably salient stimulus frequently cited as leading to the misidentification of wins is near-misses. Near-misses occur when the outcome of an event closely resembles a winning outcome, even though it is a loss. The current study intended to further investigate the effects of near-misses relative to wins and losses on player's inter-trial latencies and the presence of the feedback-related negativity (FRN) and P300 event related potentials (ERPs) in a game of war card game. FRN is a negative fronto-central ERP component occurring 200 and 300 ms post-feedback, and P300 is positive centro-parietal ERP component occurring 300 to 600 ms post-feedback. The results of this study revealed decreased amplitudes for FRN and an unanticipated ERP component, N1, following winning outcomes than near-miss or loss outcomes. No differences were observed in latency to resume playing, average bet amount placed on the following round, or the amplitude of an additional unanticipated ERP component, P2. The P300 ERP component was not observed following feedback presentation onset. Near-misses and losses showed no differences across any of the measures included in the current study, indicating the lack of an observed near-miss effect when measuring from feedback presentation. Further studies are needed in order to assess the presence of any possible near-miss effects when measuring from card presentation onset rather than feedback presentation.

DEDICATION

This thesis is dedicated to my fellow grad students and to my parents, Eric and Trish Wylie, for their endless support.

ACKNOWLEDGEMENTS

The author wishes to thank her professors for their advice and support. The author would also like to thank Dr. Carlson, Jeremy Andrzejewski, and the entirety of the CABIN lab for offering crucial guidance and for allowing the use of their equipment. Finally, the author would like to thank her research assistants, Emily Devaney, Scotti Howard, and Luke Whitehouse for their assistance and support, above and beyond what was expected of them.

This thesis follows the format prescribed by the APA Style Manual and the Department of Psychological Science.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Gambling is any behavior where there is a risk of winning or losing an amount of a valued commodity, such as money, contingent upon the chance outcome of a game or event (Whelan et al., 2007). In the United States alone, gambling is ever-present with yearly reported gambling revenues totaling over $150 billion. In 2017, United States casinos (commercial and tribal combined) reported $73.15 billion in gross revenue. Lottery revenue comprised $80.55 billion, and online gambling made up another $247.5 million (gaming.unlv.edu/reports). The American Gambling Association (2018) reported that in 2017, the gaming revenue for the United States was $40.28 billion. This represents a 3.4 percent increase from 2016. With 2017's revenue, it can be seen that, in all but one year since 2009, the United States commercial casino industry has shown grown. The 2018 reversal of a ban on sports betting by the United States Supreme Court has increased the likelihood that gambling revenues in upcoming years will be further increased in the United States (American Gambling Association, 2018). In 2013, 76.1 million people gambled at least once, representing 32% of the adult population in the United States (American Gaming Association, 2013). Further, it was estimated by the National Gambling Impact Study Commission (1999) that 86% of United States citizens have gambled in some form during their lifetime.

Although gambling is highly prevalent in the United States, it is not a problem behavior for many participants and is widely accepted. The American Gaming Association (2013) reported that 47% of participants identified gambling as a non-problematic behavior for themselves, with an additional 38% saying that while it is

problematic for themselves, gambling is an acceptable activity for others. Despite this acceptance, gambling is a problematic and addictive behavior for millions of Americans. Gambling difficulties are a prevalent enough issue in the United States to be included in the American Psychological Association's (APA) fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5). The DSM-5 defines Gambling Disorder as being characterized by persistent and recurring problematic gambling that results in clinically significant impairment or distress that is not better classified as mania. Those with a gambling disorder will have exhibited at least four of the following over the past year: (a) the need to gamble with increasing amount of money to achieve the desired level of excitement; (b) restlessness and/or irritability upon trying to stop or reduce gambling behaviors; (c) a history of unsuccessful attempts to stop or reduce gambling behaviors; (d) preoccupation with gambling, (e) engaging in gambling behaviors when feeling distressed; (f) "chasing" losses by returning and trying to regain lost money; (g) dishonesty used to conceal the extent of gambling behaviors; (h) putting significant relationships, jobs, or educational opportunities in jeopardy because of gambling behaviors; and (i) relying on money from others to aid financial crises caused by gambling. Gambling disorder can be classified as episodic, if symptoms diminish for a multi-month period between periods of problem gambling. Gambling disorder may be classified as persistent, if symptoms persist over a multi-year period. The disorder can be labeled as in early or sustained remission as well, based on a lack of met criteria for between 3 and 12 months or over 12 months, respectively. Those with gambling disorder will also be diagnosed as having a mild (4-5 criteria met), moderate (6-7 criteria met), or severe (8-9 criteria met) disorder (American Psychiatric Association, 2013).

Prior to the classification of problem gambling as an addictive disorder called "gambling disorder" in the DSM-5, problem gambling was classified as "pathological gambling" in the DSM-IV (American Psychiatric Association, 1994). The diagnostic criteria were similar to that of the DSM-5, but required individuals to have exhibited at least five of the symptoms over the past year, and included a criterion of committing illegal acts to finance gambling behaviors. Based on the DSM-IV criteria, up to 4% of adults in the United States could be diagnosed as problem gamblers, and up to 2% as pathological gamblers (Petry, 2005; Shaffer & Hall, 2001). The changes made to the DSM-5 served to further increase the acceptance of gambling as a psychiatric disorder, encourage awareness and screening for the disorder, and to promote future research into the treatment of the disorder (Petry, Bowden-Jones, & George, 2013). It is yet unclear how the reclassification of problem gambling has affected these statistics, but it is likely that the statistics would be raised somewhat, as a result of the decrease in number of criteria needed to classify an individual as being a problem gambler.

In order increase awareness and screening for gambling disorder and to develop effective treatments, the underlying conditions leading to the development of problem gambling behaviors must be understood. In giving an overview of the available treatments for pathological gamblers (as they were formerly classified) Porter and Ghezzi (2006) reported that therapies for pathological gamblers were based heavily on assumed pathology, which tended to infer causal relationships between hypothetical constructs and provided variable levels of effectiveness to individuals. Porter and Ghezzi (2006) suggested that treatments instead focus on experimental analysis of the environmental contingencies that can be used to predict and control gambling behaviors. As the analysis

of environmental contingencies is the focus of behavior analysis, these proposed treatments would be behavior analytic in nature.

With the Supreme Court's reversal of the ban on sports betting and the rise of technology and subsequent increase in electronic gambling machine (EGM) use, opportunities for gambling have expanded exponentially over the past decades. This raises the possibility that more and more Americans will be affected by gambling disorder, further solidifying the social significance of the problem (Dixon et al., 2015).

Within the behavior analytic gambling literature, the misidentification of outcomes has been shown to affect gambling behaviors in both healthy and problem gamblers (Barton et al., 2017). Two notably salient stimuli frequently cited as leading to the misidentification of wins by players are near-misses and losses disguised as wins (LDW). Near-misses occur when the outcome of a game or event closely resembles a winning outcome, even though it is a loss. A classic example of a near-miss is when an individual gets two matching symbols on a three reel slot machine with a third matching symbol located above or below the pay line of the third reel (Daar & Dixon, 2015). Losses disguised as wins occur when an individual wins back some money, but less than what they wagered, resulting in an overall loss (Dixon et al., 2010). These outcomes are typically designed to resemble winning outcomes. An example of an LDW can be seen when an individual places a five cent per-line wager on a slot machine with five payout lines and wins fifteen cents by matching three symbols on one of the payout lines. The slot machine is programmed to respond as if this is a winning outcome for the player, flashing lights, showing animations, and playing music. In reality, the player lost ten cents on that round and the outcome should be considered to be a loss.

Skinner (1953) discussed the idea of near-miss using the example of a three reel slot machine. Through a history of receiving large payouts for three matching symbols, an "almost jackpot" outcome will be established as a conditioned reinforcer. In these "almost jackpot" outcomes, the player receives two matching symbols and a third match just above or below the payout line. Skinner stated that casinos could reinforce players more frequently without any additional payouts through the use of such "almost jackpot" outcomes. The observed tendency to categorize near-miss outcomes as more valuable or predictive of a win has been referred to as the near-miss effect (Reid, 1986).

Recently, Barton et al. (2017) published a systematic literature review detailing the behavioral, psychological, and psychobiological effects of both near misses and LDWs to gain further understanding of the precise influences of such salient stimuli on players. The literature review included 51 peer-reviewed studies using human participants that were published between 1991 and 2015. Regarding the behavioral effects of near-misses, three studies investigated whether the presence of near-misses influenced machine or symbol holding choice. Near-misses were found to have no influence on which reels participants chose to hold (Clark et al., 2012). Players were also shown to be unable to differentiate between machines offering differing rates of near-misses (Maclin et al. 2007; Kurucz & Ko¨rmendi 2012). Maclin et al. (2007) did however, report a preference for machines offering near-miss outcomes after a sequence of loss outcomes.

Another behavioral aspect, post reinforcement pauses (PRP) was examined by three studies with differing results. Belisle and Dixon (2015) found that players pause longer following a near-misses than losses. This effect was intensified by the number of

matching symbols visible on the machine. Conversely, Dixon et al. (2013) described shorter pauses following near-misses than wins or losses. An additional study found no difference in pausing following near-misses than wins or losses (Worhunsky et al., 2014).

A final behavioral aspect of near-misses is their influence on gambling behaviors across a session. Three studies determined no effect on the number of times players gambled in sessions that included near-misses (Whitton & Weatherly, 2009; Sundali et al., 2012; Devos et al., 2015). In contrast, three other studies found that players tended to extend the length of their gaming session after experiencing near-misses (Griffiths, 1991; Kassinove & Schare, 2001; Coˆte´ et al., 2003). Studies examining betting behavior produced inconsistent results as well. Wu et al. (2015), found no difference in bet amounts placed by players on spins following a near-miss outcome on the previous spin. One other study found players bet less on the spin following a near-miss (Sundali et al., 2012), and one study reported players to bet more following a near-miss, or win, than following a loss (Alicart et al., 2015).

When reviewed as a whole, the literature regarding the behavioral effects of near-misses lacks consistent results. One notable inconsistency is in the effect of near-miss outcomes on PRPs (discussed above) in players. Additionally, while three studies found players played equally long in gaming sessions with and without the presence of near-misses, three others found that that players extended the length of their gaming session after experiencing near-misses. There is however, evidence that players are not readily able to distinguish between machines offering differing levels of near-miss outcomes, that near-misses motivate continued play, and that a string of losses can shift player preference toward machines offering higher densities of near-misses. Overall, more

research is needed to clarify and pinpoint the effects of near-misses on gambling behavior.

As well as the previously described behavioral effects, some studies examining near-misses have used electroencephalography (EEG) recordings to further assess the effects of near-misses. Using EEG, the psychophysiological effects of these outcomes can now be examined. Some commonly cited ERPs in gambling research are feedback-related negativity (FRN), a fronto-central ERP component occurring as a negative deflection 250 and 350 ms after the onset of feedback. Increased FRN magnitudes are typically observed when feedback signals monetary loss compared to gain (San Martin et al., 2010; Toyomaki & Murohashi, 2005; Yeung et al., 2005) and following the presentation of negative feedback compared to positive feedback (Gehring & Willoughby, 2002; Hajcak et al., 2005). Reduced FRN amplitude is also seen after winning outcomes compared to losses (Lole et al., 2013). Further research discovered that this reduction to negativity to wins is actually a separate ERP called feedback-related positivity (FRP; also referred to as reward positivity or RewP) that is characterized by greater amplitude positive deflections following reward in the same latency window as the FRN (250–350 ms after the onset of feedback; Holroyd et al., 2008).

From FRN and FRP evolved the use of the term RewP. It is argued that RewP more accurately reflects relevant neural activity associated with reward processing as RewP amplitudes are relatively larger for rewarding or positive feedback compared to negative or neutral feedback (Holroyd et al., 2008; Proudfit, 2015). RewP is thought to index reward-related mesocortical dopamine system activity (Holroyd & Coles, 2002; Holroyd et al., 2004). Supporting this is that RewP amplitude has been linked to ventral

striatum and other reward system circuitry activity (Carlson et al., 2011; Becker et al., 2014), along with volumes of dopaminergic midbrain structures such as the ventral tegmental area (VTA; Carlson et al., 2015). RewP amplitudes are elevated in individuals with higher levels of self-reported reward responsiveness (Bress & Hajcak, 2013) and is sensitive to reward magnitude (San Martín et al., 2010). RewP amplitudes can then be said to represent a neural index of reward reactivity (Tunisen et al., 2019). Despite this, the use of FRN and FRP remains prevalent in gambling literature.

Following FRN/FRP/RewP, the P300, a centro-parietal ERP component occurs as a positive deflection 300 to 600 ms after the onset of feedback. P300 is a parietally distributed ERP component sensitive, among many things, to the occurrence of infrequent, task- relevant events (Donchin & Coles, 1988). P300 is also known as an indicator of positive outcomes as it is observed in greater amplitude following winning outcomes as opposed to losing ones (Hajcak et al., 2007; Toyomaki & Murohashi, 2005; Wu & Zhou, 2009; Zhou et al., 2010).

In a study involving near-miss outcomes, Lole et al. (2015) found near-misses to elicit reduced FRN amplitudes compared to losses in both problem gamblers and healthy controls. Conversely, Ulrich and Hewig (2014) reported significant increases in FRN amplitudes following a near-miss than other outcome types. From these results, there is no clear indication of whether near-misses result in increased or decreased FRN amplitudes than losses, as results have been produced suggesting both alternatives. As the near-miss effect occurs when some losses are regarded as being closer to a win than other losses (Reid, 1986), and decreased FRN amplitudes are seen following wins than losses (San Martin et al., 2010; Toyomaki & Murohashi, 2005; Yeung et al., 2005), evidence of

a near-miss effect would be observed if near-misses resulted in decreased FRN amplitude than losses. With regard to P300, increased amplitude has been observed following near-misses than other outcome types (Ulrich & Hewig, 2014). Similarly, Alicart et al. (2015) also provided evidence for elevated P300 amplitude following wins and near-misses, but not losses. As increased P300 amplitude is seen following wins than losses (Hajcak et al., 2007; Toyomaki & Murohashi, 2005; Wu & Zhou, 2009; Zhou et al., 2010), evidence of a near-miss effect would be observed if greater P300 amplitudes are seen following near-misses than losses.

As the literature indicates, there are many unclear and contradicting results regarding the behavioral effects of near-misses. Players have been seen to pause longer after near-misses than losses, shorter after near-misses than losses, and no different after near-misses than losses. Further, the psychobiological effects of near-misses have only begun to receive examination. Players have shown increased FRN following near-misses than losses, but this has not been demonstrated outside of slot machine EGMs. Due to the lack of clear results and limited variety of EGMs examined thus far, further research on near-misses utilizing different EGMs may provide a greater understanding of such outcomes.

The current study seeks to examine near-miss outcomes (relative to wins and losses) in a game of war card game using both behavioral and psychophysiological measures. An EGM design was chosen for the current study, as EGMs typically deliver a large quantity of outcomes over a short amount of time have been shown to be useful in experiments attempting to study behavioral effects (Dixon et al., 2009a; Dixon et al., 2009b) and ERPs (Lole et al., 2013; Lole et al., 2015). A game of war card game design

was chosen for use in the current study as near-misses are a naturally occurring outcome of the game, the game has not yet been utilized in the examination of near-miss effects, and the simple game design with few stimuli lends itself to EEG research. As there are unclear and contradictory results regarding the effects of near-misses, it is hypothesized that the results of this study will reveal differences in behavioral inter-trial latencies, FRN amplitude, and P300 amplitude following near-misses than following wins or losses.

Research Hypothesis

Null Hypothesis 1: There will not be a statistically significant difference in behavioral inter-trial latencies, FRN amplitude, and P300 amplitude following near-misses than following wins or losses.

Ho: μ Near-Miss = μ Non-Near-Miss

Alternative Hypothesis 1: There will be a statistically significant difference in behavioral inter-trial latencies, FRN amplitude, and P300 amplitude following near-misses than following wins or losses.

H1: μ Near-Miss $\neq$ μ Non-Near-Miss

METHODS

Participants

32 students (female = 23, right-handed = 28) between the ages of 18-52 (*M* = 21.84, *SD* = 6.28) provided informed consent and participated in the current study for class credit following in-class recruitment at a Midwest university. The South Oaks Gambling Screen (SOGS; *M* = .22, *SD* = .66, IOA = 93.75%; Lesieur & Blume, 1987) was used to rate the severity of problem gambling behaviors in participants from 0 to 20. Although no individual's met the criteria, any individual who scored a five or above would have been given information on obtaining help for problem gambling behaviors, thanked for their time, and excused from the study. As near-misses have been shown to be salient to both healthy and problem gamblers, and in order to prevent any potential concerns regarding the promotion of pathological behaviors, the proposed study did not assess those with higher SOGS severity scores (Barton et al., 2017).

Procedure

Following the acquisition of informed consent, participants completed the SOGS (Lesieur & Blume, 1987). Participants then had the EEG net placed on their heads and the impedances of each electrode assessed and reduced to appropriate levels (described below). Participants were then shown an instructional PowerPoint presentation regarding how to play the game. Within the presentation, it was described how the goal will to be to win as many rounds as possible and thus earn the maximum amount of extra credit. The

participant was then asked if they had any further questions prior to beginning the game. Practice trials were then conducted, moving automatically to testing trials after mastery criterion (18/20 trials correct) was reached by participants. Following the session, participants were debriefed and any questions participants had about the study were resolved.

Gambling task

The task was administered using an application created with Microsoft Visual Basic (2015). The task was designed to simulate a game of war card game, where the player and an opponent each flip over a playing card and the player with the card of the highest value wins. The objective of the game is to win as many rounds as possible. Participants first played through a block of 20 practice trials until they answered at least 18/20 trials correct. A trial was marked as correct if the player correctly identified whether they had lost or won. Training trials were followed by five blocks of 20 testing trials. After every block of 20 trials, there was a 25,000 ms rest period where the participant was instructed to stare at the fixation point on the screen. Players were allotted 100 credits at the start of their training trials and 600 credits at the start of their testing trials. These values were selected as to never allow the player to reach a negative amount of credits before the end of the trails.

At the start of each round, the participant selects whether they want to place a bet of 1 or 5 credits for the round using the “f” or “j” keys respectively. Following this, the trial begins with a fixation point on a blank screen for 500 ms. This was then followed by the presentation of two cards, one for the player on the left half of the screen and one for

the opponent on the right. Each set of cards were selected randomly and without repeating from a list of 120 preset trial outcomes. The bank of usable trials was reset following the completion of the training trails. Cards were shown on the screen horizontally with a fixation point between them and remained visible for 1000 ms. If the participant's card was of a higher value than their opponent's card, the participant won the round and was instructed to press "f", and if the participant's card was of a lesser value than their opponent's card, the participant lost the round and was instructed to press "j". The game used a standard set of 52 playing card stimuli. Aces were counted as the highest value card in the game. Participants used their left pointer finger to press the 'f' key and their right pointer finger to press the 'P' key. After the participant responded, a fixation point appeared on a blank screen for 500 ms. Participant feedback was then shown on the screen for 1000 ms. Participant feedback said either "You Win!" in green text, or "You Lose!" in red text, and was accompanied by either a triumphant audio clip or a brief, sharp audio clip respectively. Figure 1 illustrates the game sequence for a sample trial.

The game consisted of win, loss, and near-miss outcomes. As the rules of War dictate, a win was defined as the player having a higher valued card than their opponent. Losses were defined as the player having a lower valued card than their opponent by at least 4 points, and a near-miss occurred when the player had a lower valued card than their opponent by at most 3 points. These values for defining losses and near-misses were chosen as they are consistent with outcomes that would be considered near-misses in previous studies (Dixon 2010; Dixon et al., 2009). Of the 120 predetermined card pairings, 40 were winning outcomes for the player, 40 were losses, and 40 were near-

misses. It was determined that at least 20 usable trials of each type were required to capture both the FRN and P300 ERPs (Marco-Pallares et al., 2010; Cohen & Polich, 1997). Forty trials of each type were selected as to have a higher likelihood of obtaining usable EEG recordings from all players.

EEG recording

EEG data was recorded for all participants using an EGI 64 electrode Hydro Cel Geodosic Sensor Net (Electrical Geodesics. Inc., Eugene, OR). Electrodes were placed according to the 10-20 system in order to standardize net placement across participants, and electrode Cz was used as the reference electrode. Impedances were reduced to a maximum of 75 kΩ for cap, EOG, and reference electrodes. Potentials were sampled at a rate of 500 Hz. Data received from the net were sent to Net Station and all stimulus changes in the game were sent to Net Station through E-Prime and Visual Basic. During the experiment, markers at various points in the trials were flagged to allow the EEG data to be time-locked. The use of such flags allows the comparison of ERP's across participants. Flagged stimulus changes included that player placing bets, the presentation of a fixation point, the presentation of the cards, the player making a response, the presentation of feedback, the end of the training trials, the onset of rest periods, and the end of the game.

Preprocessing and analysis

Net Station's Waveform Tools were used to process the obtained EEG data. The continuous data were filtered through a high pass filter at .1 hz and a low pass filter at 30

hz. Data for each of the participant EEGs were segmented from 100 ms pre-feedback presentation to 500 ms post-feedback presentation. Net Station's artifact detection tools were then used to identify eye-blinks as deflections of at least 140 μV at the net's eye-blink electrodes, eye-movements as deflections of at least 55 μV at the net's eye-movement electrodes, and bad channels as channels with fast average amplitudes of at least 200 μV. Segments containing eye-blinks, eye-movements, or more than 10 bad channels were excluded from further analysis. Any channel marked as bad in at least 20% of segments was replaced using data interpolated by Net Station from the other channels. Participants with less than 20 segments for each trial type were excluded from further analysis leaving 26 participants (female = 18, right-handed = 23) aging from 18-52 (M = 21.73, SD = 6.82).

The segments for each trial type were then averaged for each participant, to produce an average waveform for wins, losses, and near-misses for each of 26 subjects. The averaged segments then underwent re-referencing where they were referenced to the average of all the electrodes, followed by baseline corrections from -100 to 0 ms. Following visual inspection, average FRN amplitudes were extracted from 230 to 330 ms for electrodes 4, 6 (Fz), and 8. Figure 2 shows the electrode layout used in the current study. These electrodes were chosen as they align with previous research and showed the most prominent negative deflections upon visual analysis (Lole et al., 2015). Average P300 amplitudes were not extracted, as the P300 was absent from the data upon visual inspection. However, N1 and P2 ERPs were observed upon visual inspection. N1 was observed as a negative deflection occurring 80 to 170 ms post-feedback onset, and P2 was observed as a positive deflection occurring 172 - 266 ms post-feedback onset.

Average N1 and P2 amplitudes were then extracted from the aforementioned timeframes. Both ERPs were analyzed at electrodes VREF (Cz), 4, 7, and 54. These electrodes were chosen as they align with previous research and showed the most prominent wave deflections upon visual analysis (Du et al., 2016).

In order to examine if the ERP components are seen following feedback or card presentation, segments were then also created, time-locked to card presentation. Due to limitations in the study design (stimulus flagging), EEG data time-locked to card presentation was unable to be assessed by trial type in the current study. The data was thus analyzed as a whole, without regard to trial type. Following visual inspection, average FRN amplitudes were extracted from 260 to 360 ms for electrodes 4, 6 (Fz), and 8. These electrodes were chosen as they align with previous research and showed the most prominent negative deflections upon visual analysis (Lole et al., 2015). Average P300 amplitudes were extracted from 220-380 ms post-feedback onset for electrodes 33, 34 (Pz), 36, and 38. These electrodes were chosen as they align with previous research and showed the most prominent positive deflections upon visual analysis (Lole et al., 2015). As in the segments time-locked to feedback presentation, the segments time-locked to card presentation showed the presence of N1 and P2 ERPs upon visual inspection. N1 was observed as a negative deflection occurring 80 to 170 ms post-feedback onset, and P2 was observed as a positive deflection occurring 170 - 260 ms post-feedback onset. Average N1 and P2 amplitudes were then extracted from the aforementioned timeframes. Both ERPs were analyzed at electrodes VREF (Cz), 4, 7, and 54. These electrodes were chosen as they align with previous research and showed the

most prominent wave deflections upon visual analysis (Du et al., 2016). All other aspects of data processing were performed as previously described.

Statistical analysis

In order to assess the relationship between age and SOGS score, gender and SOGS score, average latency to resume playing following each trial type and SOGS score, and average bet amount placed following each trial type and SOGS score, a series of correlations were conducted. For age and SOGS score, a spearman correlation was conducted due to the skewed distribution of ages and SOGS scores. A point-biserial correlation was used to assess gender and SOGS score as gender was only recorded as male or female for the current study and was thus dichotomous. No participants reported their gender as being anything other than male or female for the current study. The data for latency to resume playing and average bet amount placed following each outcome type and its relationship to SOGS score were assessed using a series of spearman correlations as well due to the skewed nature of the SOGS scores.

One-way repeated measures ANOVAs were conducted in order to assess the effect of trial type (win vs. loss vs. near-miss) on latency to resume playing and bet amount placed. For the EEG data, a series of repeated measures factorial ANOVAs were conducted to assess the effects of trial type and electrode on FRN, N1, and P2 amplitudes following feedback onset. Finally, to assess the effects of electrode on FRN, P300, N1, and P2 amplitudes following the onset of card presentation, a series of one-way repeated measures ANOVAs were conducted. Following the completion of the ANOVAs, main effects for trial type (when applicable), electrode, and the trial type and electrode

interaction (when applicable) were reported, followed by Bonferroni corrected pairwise comparisons. Statistical significance was determined using an alpha level of .05.

RESULTS

Behavioral data

A spearman correlation revealed no correlation between age and SOGS score, r_s (30) = .26, p = .15. A point-biserial correlation revealed no correlation between gender and SOGS score, r (30) = -.22, p = .23. A series of three spearman correlations found a significant correlation between SOGS score and latency to resume playing after wins (r_s (29) = -.37, p = .04), and no correlation between SOGS score and latency to resume playing following losses (r_s (29) = .07, p = .70), or near-misses (r_s (29) = -.07, p = .71). With regard to bet amounts placed, a series of three spearman correlations found no correlation between SOGS score and bet amount placed following wins (r_s (30) = .08, p = .65), losses (r_s (30) = .19, p = .30), or near-misses (r_s (30) = .13, p = .48).

Of the 32 participants in the study, behavioral inter-trial latency, or latency to resume playing (in sec) was analyzed for 31 participants. The data of one participant was unable to be assessed due to technical difficulties during the session. Latency to resume playing was measured from the time the feedback was presented to the time the player placed their next bet. Figure 3 illustrates the average latency to resume playing, separated by trial type. After applying the Greenhouse-Giesser correction for violation of the assumption of sphericity, results from a one-way repeated measures ANOVA indicate that there was no main effect of trial type on latency to resume playing following feedback, F (1.81, 54.2) = 1.15, p = .32, η^2 = .04. Bonferroni corrected pairwise comparisons indicate that players showed no difference in time to resume playing after a win (M = 1.63, SE = .04) than after a near-miss (M = 1.56, SE = .06, p = .72) or a loss (M

= 1.56, *SE* = .05, *p* = .41). Players also showed no difference in time to resume playing after a near-miss than a loss (*p* = 1.00).

As with the behavioral inter-trial latency data, bet amount placed was analyzed for 31 of the 32 participants. The data of one participant was unable to be assessed due to technical difficulties during the session. Figure 4 illustrates the average bet amount placed following wins, near-misses, and losses. After applying the Greenhouse-Giesser correction for violation of the assumption of sphericity, results from a one-way repeated measures ANOVA indicate that there was no main effect of trial type on bet amount placed for the following round, F (1.15, 34.63) = 3.45, p = .07, η^2 = .10. Bonferroni corrected pairwise comparisons indicate that players did not place different bet amounts following wins (*M* = 2.49, *SE* = .20) than following near-misses (*M* = 2.21 *SE* = .17, *p* = .26) or losses (*M* = 2.19, *SE* = .18, *p* = .15), or following near-misses than losses (*p* = 1.00).

EEG data

Of the 32 participants in the study, EEG data was analyzed for 26 participants. The data of 6 participants did not meet the aforementioned criteria of at least 20 usable segments per trial type. In order to assess the results of the EEG data segmented from feedback onset, repeated measures factorial ANOVAs were conducted. Figure 5 illustrates the average waveform of all usable participant EEGs combined, or the grand averaged waveforms, at all electrodes assessed in the current study.

After applying the Greenhouse-Giesser correction for violation of the assumption of sphericity, results from a 3 x 3 repeated measures ANOVA assessing the effect of trial

type (win vs. loss vs. near-miss) and electrode (4 vs. 6 vs. 8) on mean FRN amplitudes indicated that there was not a main effect of trial type on average FRN amplitude, F (1.99, 49.76) = .51, p = .60, η^2 = .02. Bonferroni corrected pairwise comparisons indicate that there was no difference in mean FRN amplitude following a win (M = -1.14, SE = .49) than a loss (M = -1.34, SE = .57, p = 1.00) or a near-miss (M = -1.54, SE = .53, p = 1.00). Players also showed no difference in average FRN amplitude following a near-miss than a loss (p = 1.00). There was not a main effect of electrode on average FRN amplitude, F (1.09, 27.14) = 1.62, p = .22, η^2 = .06. Bonferroni corrected pairwise comparisons indicate that there was no difference in mean FRN amplitude at electrode 4 (M = -1.63, SE = .37) than at electrode 6 (M = -1.39, SE = .53, p = 1.00) or at electrode 8 (M = -1.00, SE = .63, p = .59). No difference in average FRN amplitude was seen at electrode 6 than at electrode 8 (p = .09). Additionally, there was a significant interaction between trial type and electrode, F (2.27, 56.77) = 10.63, p < .001, η^2 = .30. Bonferroni corrected pairwise comparisons indicate that at electrode 4, wins (M = -.70, SE = .41) resulted in less FRN amplitude than losses (M = -1.94, SE = .45, p = .003) or near-misses (M = -2.25, SE = .37, p < .001). No difference was seen in FRN amplitude at electrode 4 between losses and near-misses (p = .94). At electrode 6, wins (M = -1.45, SE = .54) resulted in no difference in FRN amplitude than losses (M = -1.26, SE = .62, p = 1.00) or near-misses (M = -1.46, SE = .59, p = 1.00). No difference was seen in FRN amplitude at electrode 6 between losses and near-misses (p = 1.00). At electrode 8, wins (M = -1.28, SE = .65) resulted in no difference in FRN amplitude than losses (M = -.84, SE = .74, p = 1.00) or near-misses (M = -.89, SE = .72, p = 1.00). No difference was seen in FRN amplitude at electrode 6 between losses and near-misses (p = 1.00).

After applying the Greenhouse-Giesser correction for violation of the assumption of sphericity, results from a 3 x 4 repeated measures ANOVA assessing the effect of trial type (win vs. loss vs. near-miss) and electrode (VREF vs. 4 vs. 7 vs. 54) on mean N1 amplitudes indicated that there was not a main effect of trial type on average N1 amplitude, F (1.27, 31.69) = 2.93, p = .09, η^2 = .11. Bonferroni corrected pairwise comparisons indicated decreased N1 amplitude following wins (M = -2.16, SE = .32) than a loss (M = -2.82, SE = .22, p = .03). No difference in N1 amplitude was seen following a win than following a near-miss (M = -2.81, SE = .28, p = .38). Players also showed no difference in average N1 amplitude following a near-miss than a loss (p = 1.00). There was a main effect of electrode on average N1 amplitude, F (1.54, 38.48) = 6.80, p = .006, η^2 = .21. Bonferroni corrected pairwise comparisons indicate that there was decreased N1 amplitude seen at electrode VREF (M = -2.08, SE = .28) than at electrode 4 (M = -3.05, SE = .25, p = .02). There was no difference in average N1 amplitude when comparing electrode VREF to electrode 7 (M = -2.88, SE = .25, p = .10) and electrode 54 (M = -2.37, SE = .26, p = 1.00). There was no difference in N1 amplitude seen at electrode 4 than electrode 7 (p = .93), and significantly increased average N1 amplitude seen at electrode 4 than electrode 54 (p = .001). There was also significantly increased average N1 amplitude seen at electrode 7 than 54 (p = .02). Additionally, there was not a significant interaction between trial type and electrode, F (1.08, 26.96) = 2.91, p = .10, η^2 = .10. Bonferroni corrected pairwise comparisons indicate that at electrode VREF, wins (M = -3.10, SE = 1.22) resulted in no difference in N1 amplitude than losses (M = -2.04, SE = .29, p = 1.00) or near-misses (M = -1.11, SE = .71, p = .89), and losses resulted in no difference in average N1 amplitudes than near-misses (p = .61). At electrode 4, wins (M

= -2.06, *SE* = .29) resulted in decreased N1 amplitude than losses (*M* = -3.33, *SE* = .28, *p* < .001) or near-misses (*M* = -3.76, *SE* = .31, *p* < .001). No difference was seen in N1 amplitude at electrode 4 between losses and near-misses (*p* = .31). At electrode 7, wins (*M* = -1.92, *SE* = .32) resulted in decreased N1 amplitude than losses (*M* = -3.24, *SE* = .28, *p* < .001) or near-misses (*M* = -3.49, *SE* = .29, *p* < .001). No difference was seen in FRN amplitude at electrode 7 between losses and near-misses (*p* = .96). At electrode 54, wins (*M* = -1.57, *SE* = .28) resulted in decreased N1 amplitude than losses (*M* = -2.65, *SE* = .27, *p* < .001) or near-misses (*M* = -2.89, *SE* = .33, *p* < .001). No difference was seen in N1 amplitude at electrode 54 between losses and near-misses (*p* = 1.00).

After applying the Greenhouse-Giesser correction for violation of the assumption of sphericity, results from a 3 x 4 repeated measures ANOVA assessing the effect of trial type (win vs. loss vs. near-miss) and electrode (VREF vs. 4 vs. 7 vs. 54) on mean P2 amplitudes indicated that there was not a main effect of trial type on average P2 amplitude, *F* (1.61, 40.19) = .44, *p* = .61, η^2 = .02. Bonferroni corrected pairwise comparisons indicated no difference in P2 amplitude following wins (*M* = 2.21, *SE* = .37) than a loss (*M* = 2.41, *SE* = .23, *p* = 1.00) or a near-miss (*M* = 2.49, *SE* = .28, *p* = 1.00). Players also showed no difference in average P2 amplitude following a near-miss than a loss (*p* = 1.00). There was no main effect of electrode on average P2 amplitude, *F* (1.16, 28.98) = 3.70, *p* = .06, η^2 = .13. Bonferroni corrected pairwise comparisons indicate that there was no difference in P2 amplitude seen at electrode VREF (*M* = 3.40, *SE* = .60) than at electrode 4 (*M* = 2.13, *SE* = .31, *p* = .54), electrode 7 (*M* = 1.89, *SE* = .28, *p* = .21), or electrode 54 (*M* = 2.06, *SE* = .28, *p* = .41). There was also no difference in average P2 amplitude when comparing electrode 4 to electrode 7 (*p* = .55) and electrode

54 (p = 1.00). There was no difference in P2 amplitude seen at electrode 7 than electrode 54 (p = 1.00). Additionally, there was not a significant interaction between trial type and electrode, F (1.26, 31.67) = .56 p = .50, η^2 = .02. Bonferroni corrected pairwise comparisons indicate that at electrode VREF, wins (M = 2.79, SE = 1.14) resulted in no difference in P2 amplitude than losses (M = 3.51, SE = .49, p = 1.00) or near-misses (M = 3.89, SE = .68, p = 1.00), and losses resulted in no difference in average P2 amplitudes than near-misses (p = .93). At electrode 4, wins (M = 2.04, SE = .47) resulted in no difference in P2 amplitude than losses (M = 2.20, SE = .28, p = 1.00) or near-misses (M = 2.13, SE = .34, p = 1.00) and losses resulted in no difference in average P2 amplitudes than near-misses (p = 1.00). At electrode 7, wins (M = 1.95, SE = .43) resulted in no difference in P2 amplitude than losses (M = 1.89, SE = .27, p = 1.00) or near-misses (M = 1.83, SE = .31, p = 1.00) and losses resulted in no difference in average P2 amplitudes than near-misses (p = 1.00). At electrode 54, wins (M = 2.05, SE = .40) resulted in no difference in P2 amplitude than losses (M = 2.02, SE = .24, p = 1.00) or near-misses (M = 2.10, SE = .31, p = 1.00) and losses resulted in no difference in average P2 amplitudes than near-misses (p = 1.00).

In order to assess the results of the EEG data segmented from card presentation, one-way repeated measures ANOVAs were conducted. After applying the Greenhouse-Giesser correction for violation of the assumption of sphericity, results from a one-way repeated measures ANOVA indicate that there was no main effect of electrode on average FRN amplitude, F (1.67, 137.96) = 1.20, p = .31, η^2 = .05. Bonferroni corrected pairwise comparisons indicated no differences in average FRN amplitude at electrode 4 (M = 1.38, SE = .38) than at electrode 6 (M = -.71, SE = .60, p = 1.00) or electrode 8 (M =

.006, *SE* = .47, *p* = .96). No difference was seen in average FRN amplitude at electrode 6 than at electrode 8 (*p* = .33).

After applying the Greenhouse-Giesser correction for violation of the assumption of sphericity, results from a one-way repeated measures ANOVA indicate that there was no main effect of electrode on average P300 amplitude, F (2.44, 60.94) = .54, p = .62, η^2 = .02. Bonferroni corrected pairwise comparisons indicated no differences in average P300 amplitude at electrode 34 (*M* = 2.21, *SE* = .34) than at electrode 33 (*M* = 2.32, *SE* = .32, *p* = 1.00), electrode 36 (*M* = 2.28, *SE* = .37, *p* = 1.00), or electrode 38 (*M* = 2.40, *SE* = .35, *p* = 1.00). No difference was seen in average P300 amplitude at electrode 33 than at electrode 36 (*p* = 1.00), or electrode 38 (*p* = 1.00), or between electrode 36 and electrode 38 (*p* = 1.00).

After applying the Greenhouse-Giesser correction for violation of the assumption of sphericity, results from a one-way repeated measures ANOVA indicate that there was no main effect of electrode on average N1 amplitude, F (1.17, 29.17) = .22, p = .68, η^2 = .01. Bonferroni corrected pairwise comparisons indicated no differences in average N1 amplitude at electrode VREF (*M* = -.74, *SE* = .63) than at electrode 4 (*M* = -.75, *SE* = .29, *p* = 1.00), electrode 7 (*M* = -.39, *SE* = .23, *p* = 1.00), or electrode 54 (*M* = -.59, *SE* = .27, *p* = 1.00). No difference was seen in average N1 amplitude at electrode 4 than at electrode 7 (*p* = .49), or electrode 54 (*p* = 1.00), or between electrode 7 and electrode 54 (*p* = .21).

After applying the Greenhouse-Giesser correction for violation of the assumption of sphericity, results from a one-way repeated measures ANOVA indicate that there was no main effect of electrode on average P2 amplitude, F (1.28, 31.91) = 1.72, p = .20, η^2 =

.06. Bonferroni corrected pairwise comparisons indicated no differences in average P2 amplitude at electrode VREF (M = 1.54, SE = .61) than at electrode 4 (M = .90, SE = .35, p = 1.00), electrode 7 (M = 1.21, SE = .32, p = 1.00), or electrode 54 (M = .38, SE = .36, p = .69). No difference was seen in average P2 amplitude at electrode 4 than at electrode 7 (p = .91), and increased P2 amplitude was seen at electrode 4 than at electrode 54 (p = .01). No difference was seen in P2 amplitude between electrode 7 and electrode 54 (p = .06).

Discussion

In the current study, no near-miss effects were observed, as players did not show differences between near-miss and loss outcomes across any of the measures. Wins were, however, observed to be different from near-misses and losses on some measures. Players were observed to have decreased FRN and N1 amplitudes following wins but not near-misses or losses when examining the data from the onset of feedback. There were no differences seen in latency to resume playing or bet amount placed based on preceding trial type. There were also no differences in P2 amplitudes across trial types when measuring from feedback onset. Further, there was no observed P300 response following feedback presentation in the current study.

Behavioral results

There was no observed correlation between SOGS score and age, gender, or average bet placed following any of the trial types in the current study. This indicated that as SOGS score increased, there was no observed increase or decrease in age, gender, or bet amount placed. There was however, a significant correlation between SOGS score and average time to resume playing following wins, such that as SOGS scores increased, latency to resume playing following winning outcomes decreased. Average latency to resume playing following near-misses and losses was not correlated with SOGS score. This suggests that players were more likely to resume playing faster following wins if they scored higher on the SOGS than if they scored lower. It has previously been shown that pathological gamblers display shorter PRP's than healthy controls (Worhunsky et al.,

2014). As higher SOGS scores indicate more problematic gambling behaviors in individuals, it makes sense that these players would show decreased PRP's than players with lower SOGS scores in the current study. These mostly insignificant correlations may be due to the lack of variability in SOGS scores. Although the SOGS is scored from 0 to 20, the average score in the current study was .22 with only a .66 standard distribution. With larger variation in scores, significant correlations may emerge. It is also possible that there would continue to be no correlation between SOGS scores and age, gender, or bet amount placed following wins, losses, or near-misses even with a wider range of SOGS scores.

As Figure 3 illustrates, player's latency to resume playing was not different depending on the trial type they had just experienced. Wins did not result in longer pauses, indicating the lack of a post reinforcement pause (PRP). There was no observed difference in latency to resume playing following any of the trial types. These results support the findings of Worhunsky et al (2014) who also observed no differences in pausing between wins, losses, and near-misses. The lack of an observed PRP following losses and near-misses indicate that near-misses are not processed as a winning outcome to the player, but more similarly to a loss. The same lack of an effect was observed when examining bet amount placed following the different trial types. As can be seen in Figure 4, players did not bet differently depending on the type of trial they had just experienced. This result lends support to the results of Wu et al. (2015), who found no difference in bet amounts placed by players following near-misses than other outcome types.

Psychophysiological results

Analysis of EEG data was performed by creating segments time-locked to both feedback and card presentation. Figure 6 shows the topographical maps of the grand averaged electrocortical activity time-locked to feedback presentation for all trial types, during the time frames of the observed ERPs. In the feedback time-locked data, larger FRN amplitudes were observed for losses and near-misses compared to wins, but only electrode 4, the most central of the three electrodes assessed. There was no difference in FRN amplitude seen between losses and near-misses at electrode 4 and there were no other significant FRN effects. The results of the current study support the results of previous studies showing increased FRN amplitudes following negative/loss feedback (Gehring & Willoughby, 2002; Hajcak et al., 2005; Toyomaki & Murohashi, 2005; Yeung et al., 2005). The lack of a difference in FRN amplitude between near-miss and loss outcomes shows a lack of a near-miss effect, as there is no indication that losses and near-misses are processed any differently by the player. When analyzed from card presentation, the effect of trial type on average FRN amplitude was unable to be assessed. There was no difference in electrode however. When comparing the feedback and card presentation data, decreased FRN amplitudes are seen following card presentation than following feedback. This result is confounded by the inability to examine the card time-locked data by trial type however.

Although it was not anticipated, the N1 ERP was present in the feedback time-locked data. This early sensory ERP presents as a negative deflection occurring roughly 100 ms after feedback presentation that is thought to reflect mechanisms involved in the initial sensory or attentional selection process (Park et al., 2017). The analysis of N1

amplitudes revealed greater N1 amplitude for losses compared to wins, but near-misses were not significantly different from wins or losses. Electrodes 4 and 7 captured the he greatest N1 amplitudes. Further, all electrodes apart from VREF (Cz) showed increased N1 amplitude to losses and near-misses than wins, but near-misses were not different than losses. Although Lole et al. (2015) did see the presence of the N1 component as well, no differences were observed between trial types as was seen in the current study. In the current study, feedback involved two different tones. One tone was presented as part of the feedback for wins, and the other tone for losses and near-misses. This could explain the observed differences in N1 amplitude for losses and near-misses compared to wins on three of four electrodes, and the non-significant difference between losses and near-misses as they were accompanied by the same tone. It is also possible that the observed effect is not a sensory-related effect to the presented tones, but instead represents the players' reactions to the feedback indicating a win or loss. If these N1 amplitude differences are in fact a reaction to feedback indicating wins and losses, this indicates a lack of an observed near-miss effect as near-misses and losses were not processed differently by players. When analyzed from card presentation, there was no difference in electrode. When comparing the feedback and card presentation data, decreased N1 amplitudes are seen following card presentation than following feedback. This result supports the theory that the feedback related audio clips affected N1 amplitudes, but this result is confounded by the inability to examine the card time-locked data by trial type.

Another unanticipated ERP found in the feedback time-locked data was P2. This ERP presents as a positive deflection occurring roughly 200 ms after feedback

presentation. The analysis of P2 amplitudes revealed no differences in average P2 amplitude across trial type or electrodes. Although it was discernable under visual inspection, P2 was not observed to have any sensitivity to the assessed measures. In previous studies, P2 was shown to show larger amplitudes following negative feedback than positive feedback (Schuermann et al., 2012). It has also been shown, however, that the P2 component is related to the unpredictability of outcomes, rather than whether the feedback is positive or negative (Polezzi et al., 2008). The findings of the current study support previous finding linking P2 to outcome predictability, rather than feedback type, as no differences were seen across trial types and there was the same level of predictability for all trial types. As with FRN and N1 amplitudes, when comparing the feedback and card presentation data, decreased P2 amplitudes are seen following card presentation than following feedback. This result has also been confounded by the inability to examine the card time-locked data by trail type, as it cannot be confirmed if there is no difference by trial type to card presentation as well as feedback.

Unlike the data time-locked to feedback onset, in the data time-locked to card presentation, visual inspection indicated the presence of P300 centering on electrode Pz. No effect of electrode was seen on P300 amplitudes, however. It is possible that this lack of an observed P300 ERP component following feedback onset is a result of the experimental design utilized. It has been shown that P300 amplitudes decrease with increases in stimulus probability (Donchin & Coles, 1988; Johnson, 1986, 1988; Polich, 1998; Pritchard, 1981). As the players in the current study knew whether they won or lost before the presentation of feedback, and feedback was always correct, players would be able to guess which feedback was coming. This may explain the lack of an observed

P300 response following feedback presentation but the presence of such responses following card presentation. If the experiment involved presenting feedback to players that was sometimes incorrect, it is likely that there would be an observable P300 response to such trials following feedback.

Combined results

When examined together, the behavioral and psychophysiological results suggest no observed differences between near-misses and losses in the current study. With regard to the behavioral effects assessed, players were found to pause no differently following wins than other outcome types (near-misses and losses). As none of the outcome types were different from each other, this denotes no significant difference in the reinforcing value of wins, losses, and near-misses on players' gambling behaviors. The amount bet by players was also not different based on the preceding trial type. As no difference was seen between near-misses and losses, no near-miss effects were observed for either latency to resume playing or bet amount placed.

These behavioral results concur with the ERP results obtained in the current study in that near-misses and losses showed no differences. It was found that there was reduced FRN amplitudes to wins relative to other outcome types. Reduced FRN amplitude for wins compared to non-wins has been well-documented in previous studies (Gehring & Willoughby, 2002; Hajcak et al., 2005; Toyomaki & Murohashi, 2005; Yeung et al., 2005). Although previous studies have found near-misses to produce decreased FRN amplitudes than losses (Lole et al., 2015), a result consistent with a near-miss effect, the same was not found in the present study. No differences in FRN amplitude were observed

between near-misses and losses. Following wins, N1 amplitudes were also seen to be reduced compared to other outcome types. This was not observed in a previous study examining the psychophysiological effects of near misses. Lole et al (2015) also found the presence of the N1 ERP in their data, but observed no differences by trial type. In the current study, near-misses and losses did not produce different N1 amplitudes. It is unclear if the observed differences in N1 amplitude to wins relative to near-misses and losses is due to the tones used in the delivery of feedback or to the feedback indicating winning versus losing. If the difference is not tone-related, this provides further evidence that near-misses and losses are not processed differently by players in the current study. Like the behavioral measures, P2 amplitudes were not different across any of the trial types in the current study. Together, these behavioral and psychophysiological effects reveal no near-miss effects seen in the game of war card game used in the current study, although wins were shown to be different from other trial types.

Limitations and directions for further research

Although this was a first step toward an analysis of both the behavioral and psychophysiological effects of near misses with a non-slot machine EGM, no near-miss effect was observed in the current study, as no significant differences between losses and near-misses were observed across any of the measures. This may be because the differences between losses and near-misses are present only following the card presentation, and not feedback presentation. It is also possible that the near-miss effect is not present in the war card game. As detailed above, a limitation of the current study involving stimulus flagging prevented the analysis by trial type of data time-locked to

card presentation. This prevented analysis by trial type at the time point where the largest differences between near-misses and losses likely occurred and hindered the comparison between feedback and card presentation time-locked data. It has been shown in previous studies that knowing the outcome before receiving feedback can affect ERPs (Nieuwenhuis et al., 2004a; Nieuwenhuis et al., 2004b). In the current study, the outcome, and thus the impending feedback, is known to the player when the cards are presented. In other words, players know if they have won or lost before the feedback is presented. For this reason, data analysis was attempted using the card presentation to segment and time-lock the data. The stimulus flagging system used unfortunately did not allow for this data to be analyzed by trial type.

If the data were able to be analyzed by trial type at this time point, it is possible that trial type differences would be observed between near-misses and losses. It is possible that requiring players to identify the outcome type as being only a win or a loss and receiving feedback saying if they won or lost had an effect on the behavior of the players. Near-miss and loss differences were assessed in the current study after plyers received feedback saying they had just lost. It is possible that this could reduce any differences that would typically be present between the two trial types if the players had not received the loss feedback first. Further, players could only transition from training trials to testing trials after they demonstrated mastery criterion of answering at least 18 trials correctly out of a block of 20 testing trials. Responses were only labeled as being correct if players identified wins as having won and near-misses and losses as having lost. In an unpublished doctoral dissertation, Daar (2016) found that when players were taught to label near-misses as being losses, differences between the two trial types were

reduced. In this way, players in the current study may have actually been taught to identify near-misses and losses as being equal, reducing any would-be differences between the two trial types.

It is also possible that the way near-misses were defined had an effect on the results obtained. Near-misses were defined as occurring when the player lost by at most three points. This maximum point difference was chosen as it was consistent with what would be labeled as a near-miss in previous studies involving point values and near-misses (Dixon 2010; Dixon et al., 2009). It is possible that the lack of any observed near-miss effects is a result of this definition of near-misses. If near-misses were considered to have occurred only when players lost by at most two points or a single point, near-miss effects may have been observed in the current study.

A further limitation of the current study is that the participants primarily consisted of entry level psychology students betting their extra credit points. With this sample, there was a very negatively skewed distribution of ages, with most participants ranging from 18-25 years of age. These participants also reported very little gambling experience, and thus extremely negatively skewed SOGS scores. With more diverse participants, significant correlations may be shown when comparing age and gender to behavioral and EEG data, as there were no significant correlations observed with the present study.

A follow-up study with corrected methodologies for stimulus flagging of data where trial type is coded into the card presentation stimulus flags will allow for a more complete analysis of any possible near-miss effects. By allowing analysis by trial type following card presentation, it is more likely that near-miss effects will be captured, if truly present, as they would be measured at the time point they are most likely to occur.

This will further illuminate whether differences are occurring following the card presentation, as that is the time when the subject learns if they won or lost, and thus what their feedback will be. By measuring free from the influence of having to label the trial as a win or a loss, and receiving feedback that you have actually won or lost, near-miss and loss trials may show some differences and indicate the presence of a near-miss effect in the game of war. Future research should analyze whether near-miss effects emerge when near-misses are defined differently, such as being at most two points or one point lower than the opponent. Finally, future research should utilize a larger range of ages and gambling experience, to determine if near misses are processed differently as age and SOGS score increase.

Conclusion

The current study was intended to address a lack of consensus in the literature about the behavioral and psychophysiological effects of near-misses and to provide further evidence for near-misses beyond those present in slot machines. Players had previously been seen to pause longer after near-misses than losses, shorter after near-misses than losses, and no different after near-misses than losses. Further, the psychobiological effects of near-misses had only begun to receive examination. Players had shown increased FRN following near-misses than losses, but this had not been demonstrated outside of studies utilizing slot machines. In the current study, a game of war card game was used in order to examine the effects of win, near-miss, and loss trial types. As there were unclear and contradictory results regarding the effects of near-misses, it was hypothesized that the results of this study would reveal differences in

behavioral inter-trial latencies, FRN amplitude, and P300 amplitude following near-misses than following wins or losses.

Analysis of the data revealed no near-miss effects in the current study, as near-misses and losses were not different from each other across any of the measures. However, wins were, observed to be different from near-misses and losses on some measures. Players showed decreased FRN and N1 amplitudes following wins but not near-misses or losses when examining the data from the onset of feedback. Latency to resume playing and average bet amount placed revealed no differences across trial types. Further, no differences were observed in P2 amplitudes based on trial types when measuring from feedback onset. Lastly, there was no observed P300 response following feedback presentation in the current study. It is possible that by measuring after feedback presentation, any near-miss effects that would have been present were not captured. It is likely that such effects would be seen following card presentation, however, as that is when the player originally discovers if they won or lost. By requiring players to indicate whether they won or lost and then providing them feedback if they won or lost before measuring for differences by trial type, any would-be differences between near-misses and losses were lost and thus any evidence of the presence of a near-miss effect in a game of war card game. Further research utilizing corrected stimulus flagging methodologies, differing criteria for defining near-misses, and participants with larger ranges of age and gambling experience is needed to further clarify the behavioral and psychophysiological effects of near-misses and particularly near-misses occurring in games beyond slot machines.

References

Alicart, H., Cucurell, D., Mas-herrero, E., & Marco-pallare´s, J. (2015). Human oscillatory activity in near-miss events. *Social Cognitive and Affective Neuroscience, 10*(10), 1405–1412. doi:10.1093/scan/nsv033.

Banks, P. J., Tata, M. S., Bennett, P. J., Sekuler, A. B., & Gruber, A. J. (2017). Implicit valuation of the near-miss is dependent on outcome context. *Journal of Gambling Studies, 34*(1), 181-197. doi:10.1007/s10899-017-9705-3

Barton, K. R., Yazdani, Y., Ayer, N., Kalvapalle, S., Brown, S., Stapleton, J., . . . Harrigan, K. A. (2017). The effect of losses disguised as wins and near misses in electronic gaming machines: A systematic review. *Journal of Gambling Studies, 33*(4), 1241- 1260. doi:10.1007/s10899-017-9688-0

Becker, M. P., Nitsch, A. M., Miltner, W. H., and Straube, T. (2014). A single-trial estimation of the feedback-related negativity and its relation to BOLD responses in a time-estimation task. *J. Neurosci.* 34, 3005–3012. doi: 10.1523/JNEUROSCI.3684-13.2014

Belisle, J., & Dixon, M. R. (2015). Near misses in slot machine gambling developed through generalization of total wins. *Journal of Gambling Studies, 32*(2), 689–706. doi:10.1007/s10899-015-9554-x.

Billieux, J., Van der Linden, M., Khazaal, Y., Zullino, D., & Clark, L. (2012). Trait gambling cognitions predict near-miss experiences and persistence in laboratory slot machine gambling. *British Journal of Psychology, 103*(3), 412–427. doi:10.1111/j.20448295.2011.02083.x

Bress, J. N., and Hajcak, G. (2013). Self-report and behavioral measures of reward sensitivity predict the feedback negativity. *Psychophysiology*50, 610–616. doi: 10.1111/psyp.12053

Carlson, J. M., Foti, D., Mujica-Parodi, L. R., Harmon-Jones, E., and Hajcak, G. (2011). Ventral striatal and medial prefrontal BOLD activation is correlated with reward-related electrocortical activity: a combined ERP and fMRI study. *Neuroimage* 57, 1608–1616. doi: 10.1016/j.neuroimage.2011.05.037

Carlson, J. M., Foti, D., Harmon-Jones, E., and Proudfit, G. H. (2015). Midbrain volume predicts fMRI and ERP measures of reward reactivity. *Brain Struct. Funct.* 220, 1861–1866. doi: 10.1007/s00429-014-0725-9

Chase, H. W., & Clark, L. (2010). Gambling severity predicts midbrain response to near-miss outcomes. *Journal of Neuroscience, 30*(18), 6180–6187. doi:10.1523/JNEUROSCI.5758-09.2010.

Clark, L., Crooks, B., Clarke, R., Aitken, M. R. F., & Dunn, B. D. (2012). Physiological responses to near-miss outcomes and personal control during simulated gambling. *Journal of Gambling Studies, 28*(1), 123–137. doi:10.1007/s10899-011-9247-z.

Clark, L., Lawrence, A. J., Astley-Jones, F., & Gray, N. (2009). Gambling near-misses enhance motivation to gamble and recruit win-related brain circuitry. *Neuron, 61*(3), 481–490. doi:10.1016/j.neuron.2008.12.031.

Clark, L., Liu, R., McKavanagh, R., Garrett, A., Dunn, B. D., & Aitken, M. R. F. (2013). Learning and affect following near-miss outcomes in simulated gambling. *Journal of Behavioral Decision Making, 26*(5), 442–450. doi:10.1002/bdm.1774.

Clark, L., Studer, B., Bruss, J., Tranel, D., & Bechara, A. (2014). Damage to insula abolishes cognitive distortions during simulated gambling. *Proceedings of the National Academy of Sciences of the United States of America, 111*(16), 6098–6103.

Cohen, J., & Polich, J. (1997). On the number of trials needed for P300. *Int J Psychophysiol, 3*, 249-255.

Coˆte´, D., Caron, A., Aubert, J., Desrochers, V., & Ladouceur, R. (2003). Near wins prolong gambling on a video lottery terminal. Journal of Gambling Studies, 19(4), 433–438.

Daar, J. H. (2016). *Losses disguised as wins in slot machines: A case of contingency confusion* (Unpublished doctoral dissertation). Southern Illinois University Carbondale, Carbondale, IL.

Daar, J. H., & Dixon, M. J. (2015) Conceptual, Experimental, and Therapeutic Approaches to Problem Gambling. In Roane H. S., Ringdahl, J. L., & Falcomata, T. S. (Ed.), *Clinical and Organizational Applications of Behavior Analysis* (pp. 350-394). San Diego, California: Academic Press.

Devos, G., Clark, L., Maurage, P., Kazimierczuk, M., & Billieux, J. (2015). Reduced inhibitory control predicts persistence in laboratory slot machine gambling. *International Gambling Studies, 15*(3), 408–421. doi:10.1080/14459795.2015.1068351.

Dixon, M. J., Harrigan, K. A., Jarick, M., MacLaren, V., Fugelsang, J. A., & Sheepy, E. (2011). Psychophysiological arousal signatures of near-misses in slot machine play. *International Gambling Studies, 11*(3), 393–407. doi:10.1080/14459795.2011.603134.

Dixon, M. J., Harrigan, K. A., Sandhu, R., Collins, K., & Fugelsang, J. A. (2010). Losses disguised as wins in modern multi-line video slot machines. *Addiction, 105*, 1819–1824.

Dixon, M. J., MacLaren, V., Jarick, M., Fugelsang, J. A., & Harrigan, K. A. (2013). The frustrating effects of just missing the jackpot: Slot machine near-misses trigger large skin conductance responses, but no post-reinforcement pauses. *Journal of Gambling Studies, 29*(4), 661–674. doi:10.1007/s10899-012-9333-x.

Dixon, M. R. (2010). The roulette near-miss effect. *Analysis of Gambling Behavior, 4*(1), 54–60.

Dixon, M. R., Nastally, B. L., Hahs, A. D., Homer-King, M., & Jackson, J. W. (2009a). Blackjack players demonstrate the near miss effect. *Analysis of Gambling Behavior, 3*(2), 56–61.

Dixon, M. R., Nastally, B. L., Jackson, J. E., & Habib, R. (2009b). Altering the near-miss effect in slot machine gamblers. *Journal of Applied Behavior Analysis, 42*(4), 913–918.

Dixon, M. R., & Schreiber, J. B. (2002). Utilizing a computerized video poker simulation for the collection of data on gambling behavior. *The Psychological Record, 52*(4), 417-428. doi:10.1007/bf03395195

Dixon, M. R., & Schreiber, J. E. (2004). Near-miss effects on response latencies and win estimations of slot machine plays. *Psychological Record, 54*(3), 335–348.

Dixon, M. R., Whiting, S. W., Gunnarsson, K. F., Daar, J. H., & Rowsey, K. E. (2015). Trends in behavior-analytic gambling and treatment. *The Behavior Analyst, 38*(2), 179–202.

Donchin, E., & Coles, M. G. (1988). On the conceptual foundations of cognitive psychophysiology. *Behavioral and Brain Sciences, 11*(03), 408. doi:10.1017/s0140525x00058246

Du, X., Choa, F., Summerfelt, A., Rowland, L. M., Chiappelli, J., Kochunov, P., & Hong, L. E. (2016). N100 as a generic cortical electrophysiological marker based on decomposition of TMS-evoked potentials across five anatomic locations. *Experimental Brain Research, 235*(1), 69-81. doi:10.1007/s00221-016-4773-7

Dymond, S., Lawrence, N. S., Dunkley, B. T., Yuen, K. S. L., Hinton, E. C., Dixon, M. R., et al. (2014). Almost winning: Induced MEG theta power in insula and orbitofrontal cortex increases during gambling near-misses and is associated with BOLD signal and gambling severity. *NeuroImage, 91*, 210–219. doi:10.1016/j.neuroimage.2014.0 1.019.

Gehring, W. J., & Willoughby, A. R. (2002). The Medial Frontal Cortex and the Rapid Processing of Monetary Gains and Losses. *Science, 295*(5563), 2279-2282. doi:10.1126/science.1066893.

Ghezzi, P. M., Wilson, G. R., & Porter, J. C. (2006). The near-miss effect in simulated slot machine play. *Gambling: Behavior theory, research, and application*, 155-170.

Gibson, B., & Sanbonmatsu, D. M. (2004). Optimism, pessimism, and gambling: The downside of optimism. *Personality and Social Psychology Bulletin*, *30*(2), 149-160.

Goldin, P. R., McRae, K., Ramel, W., & Gross, J. J. (2008). The neural bases of emotion regulation: Reappraisal and suppression of negative emotion. *Biological Psychiatry, 63(*6), 577–586. doi:10.1016/j.biopsych.2007.05.031.

Griffiths, M. D. (1990). The cognitive psychology of gambling. Journal of Gambling Studies, 6(1), 31–42.

Griffiths, M. (1991). Psychobiology of the near-miss in fruit machine gambling. *The Journal of Psychology, 125*(3), 347–357.

Habib, R., & Dixon, M. R. (2010). Neurobehavioral evidence for the ‘‘near-miss’’ effect in pathological gamblers. *Journal of the Experimental Analysis of Behavior, 93*(3), 313–328. doi:10.1901/jeab.2010.93-313.

Hajcak, G., Holroyd, C. B., Moser, J. S., & Simons, R. F. (2005). Brain potentials associated with expected and unexpected good and bad outcomes. *Psychophysiology, 42*(2), 161-170. doi:10.1111/j.1469-8986.2005.00278.x

Hajcak, G., Moser, J. S., Holroyd, C. B., & Simons, R. F. (2007). It’s worse than you thought: The feedback negativity and violations of reward prediction in gambling tasks. *Psychophysiology, 44*(6), 905-912. doi:10.1111/j.1469-8986.2007.00567.x

Harrigan, K. A., & Dixon, M. (2009). PAR sheets, probabilities, and slot machine play: Implications for problem and non-problem gambling. *Journal of Gambling Issues, 23,* 81-110. doi:10.4309/jgi.2009.23.5.

Hineline, P. N., Honig, W. K., & Staddon, J. E. R., (1977). Handbook of operant behavior.

Holroyd, C. B., & Coles, M. G. (2002). The neural basis of human error processing: Reinforcement learning, dopamine, and the error-related negativity. *Psychological Review,109*(4), 679-709. doi:10.1037//0033-295x.109.4.679

Holroyd, C. B., Larsen, J. T., & Cohen, J. D. (2004). Context dependence of the event-related brain potential associated with reward and punishment. *Psychophysiology*, *41*(2), 245-253.

Holroyd, C. B., Pakzad-Vaezi, K. L., & Krigolson, O. E. (2008). The feedback correct-related positivity: Sensitivity of the event-related brain potential to unexpected positive feedback. *Psychophysiology, 45*(5), 688-697. doi:10.1111/j.1469-8986.2008.00668.x

Horton, K., Turner, N., & Horbay, R. (2006). Do weighted reels on a slot machine distort a gambler's judgement of probability? The effect of near misses. Guelph, ON: Ontario. Problem Gambling Research Centre.

Johnson, R. (1986). A triarchic model of P300 amplitude. *Psychophysiology*.

Johnson Jr, R. (1988). The amplitude of the P300 component of the event-related potential: Review and synthesis. *Advances in psychophysiology*, *3*, 69-137.

Kassinove, J. I., & Schare, M. L. (2001). Effects of the ''near miss'' and the ''big win'' on persistence at slot machine gambling. *Psychology of Addictive Behaviors, 15*(2), 155–158.

Kurucz, G., & Ko¨rmendi, A. (2012). Can we perceive near miss? An empirical study. *Journal of Gambling Studies, 28*(1), 105–111. doi:10.1007/s10899-011-9240-6.

Lesieur, H. R., & Blume, S. B. (1987). The South Oaks Gambling Screen (SOGS): A new instrument for the identification of pathological gamblers. *American journal of Psychiatry*, *144*(9).

Lole, L., Gonsalvez, C. J., & Barry, R. J. (2015). Reward and punishment hyposensitivity in problem gamblers: A study of event-related potentials using a principal components analysis. *Clinical Neurophysiology, 126*(7), 1295–1309. doi:10.1016/j.clinph.2014.10.011.

Lole, L., Gonsalvez, C. J., Barry, R. J., & De Blasio, F. M. (2013). Can event-related potentials serve as neural markers for wins, losses, and near-wins in a gambling task? A principal components analysis. *International Journal of Psychophysiology, 89*(3), 390–398. doi:10.1016/j.ijpsycho.2013.06.011.

Lole, L., Gonsalvez, C. J., Blaszczynski, A., & Clarke, A. R. (2012). Electrodermal activity reliably captures physiological differences between wins and losses during gambling on electronic machines. *Psychophysiology, 49*(2), 154–163. doi:10.1111/j.1469-8986.2011.01290.x.

Luo, Q., Wang, Y., & Qu, C. (2011). The near-miss effect in slot-machine gambling: Modulation of feedback-related negativity by subjective value. *NeuroReport, 22*(18), 989–993. doi:10.1097/WNR.0b013e32834da8ae.

Maclin, O. H., Dixon, M. R., Daugherty, D., & Small, S. L. (2007). Using a computer simulation of three slot machines to investigate a gambler's preference among varying densities of near-miss alternatives. *Behavior Research Methods, 39*(2), 237–241.

Marco-Pallares, J., Cucurell, D., Münte, T. F., Strien, N., & Rodriguez-Fornells, A. (2010). On the number of trials needed for a stable feedback-related negativity. *Psychophysiology, 48*(6), 852-860. doi:10.1111/j.1469-8986.2010.01152.x

Martín, R. S., Manes, F., Hurtado, E., Isla, P., & Ibañez, A. (2010). Size and probability of rewards modulate the feedback error-related negativity associated with wins but not losses in a monetarily rewarded gambling task. *NeuroImage, 51*(3), 1194-1204. doi:10.1016/j.neuroimage.2010.03.031

Nastally, B. L., & Dixon, M. R. (2012). The effect of a brief acceptance and commitment therapy intervention on the near-miss effect in problem gamblers. *Psychological Record, 62*(4), 677–690.

Park, M., Kim, Y. J., Kim, D. J., & Choi, J. (2017). Differential neurophysiological correlates of information processing in Internet gaming disorder and alcohol use disorder measured by event-related potentials. *Scientific Reports, 7*(1). doi:10.1038/s41598-017-09679-z

Polezzi D., Lotto L., Daum I., Sartori G., Rumiati R. (2008). Predicting outcomes of decisions in the brain. *Behav. Brain Res. 18*, 116–122 10.1016/j.bbr.2007.09.001

Polich, J. (1998). P300 clinical utility and control of variability. *Journal of Clinical Neurophysiology, 15*, 14–33.

Porchet, R. I., Boekhoudt, L., Studer, B., Gandamaneni, P. K., Rani, N., Binnamangala, S., et al. (2013). Opioidergic and dopaminergic manipulation of gambling tendencies: A preliminary study in male recreational gamblers. *Frontiers in Behavioral Neuroscience*. doi:10.3389/fnbeh.2013.00138.

Pritchard, W. S. (1981). Psychophysiology of P300. *Psychological Bulletin, 89*, 506–540.

Proudfit, G. H. (2015). The reward positivity: from basic research on reward to a biomarker for depression. *Psychophysiology 52*, 449–459. doi:10.1111/psyp.12370

Qi, S., Ding, C., Song, Y., & Yang, D. (2011). Neural correlates of near-misses effect in gambling. *Neuroscience Letters, 493*(3), 80–85. doi:10.1016/j.neulet.2011.01.059.

Reid, R. L. (1986). The psychology of the near miss. *Journal of Gambling Behavior, 2*(1), 32-39. https://doi.org/10.1007/BF01019932.

San Martín, R., Manes, F., Hurtado, E., Isla, P., and Ibañez, A. (2010). Size and probability of rewards modulate the feedback error-related negativity associated with wins but not losses in a monetarily rewarded gambling task. *Neuroimage* 51, 1194–1204. doi: 10.1016/j.neuroimage.2010.03.031

Schreiber, J., & Dixon, M. R. (2001). Temporal characteristics of slot machine play in recreational gamblers. *Psychological Reports, 89*(1), 67-72.

Shao, R., Read, J., Behrens, T. E., & Rogers, R. D. (2013). Shifts in reinforcement signaling while playing slot-machines as a function of prior experience and impulsivity. *Translational Psychiatry*. doi:10.1038/tp.2012.134.

Sharman, S., Aitken, M. R. F., & Clark, L. (2015). Dual effects of 'losses disguised as wins' and near-misses in a slot machine game. *International Gambling Studies, 15*(2), 212–223. doi:10.1080/14459795.2015. 1020959.

Sharman, S., & Clark, L. (2015). Mixed emotions to near-miss outcomes: A psychophysiological study with facial electromyography. *Journal of Gambling Studies*. doi:10.1007/s10899-015-9578-2.

Sescousse, G., Janssen, L. K., Hashemi, M. M., Timmer, M. H., Geurts, D. E., Huurne, N. P., Cools, R. (2016). Amplified striatal responses to near-miss outcomes in pathological gamblers. *Neuropsychopharmacology, 41*(10), 2614-2623. doi:10.1038/npp.2016.43

Skinner, B. F. (1953). *Science and human behavior.* New York: Macmillan.

Stange, M. (2017). *The influence of near-miss outcomes on the physiological and subjective experience of scratch card gambling* (Master's thesis, University of Waterloo).

Stange, M., Brown, D. G., Harrigan, K., & Dixon, M. (2017). Built-in bad luck: Evidence of near-miss outcomes by design in scratch cards. *Journal of Gambling Issues,* (36). doi:10.4309/jgi.2017.36.3

Stange, M., Graydon, C., & Dixon, M. J. (2016). Increased urge to gamble following near-miss outcomes may drive purchasing behaviour in scratch card gambling. *Journal of Gambling Studies, 33*(3), 867-879. doi:10.1007/s10899-016-9662-2

Stange, M., Grau, M., Osazuwa, S., Graydon, C., & Dixon, M. J. (2017). Reinforcing small wins and frustrating near-misses: Further investigation into scratch card

gambling. Journal of Gambling Studies, 33, 47–63. doi:10.1007/s10899-016-9611-0

Sundali, J. A., Safford, A. H., & Croson, R. (2012). The impact of near-miss events on betting behavior: An examination of casino rapid roulette play. *Judgment and Decision Making, 7*(6), 768–778.

Toyomaki, A., & Murohashi, H. (2005). Discrepancy between feedback negativity and subjective evaluation in gambling. *NeuroReport, 16*(16), 1865-1868. doi:10.1097/01.wnr.0000185962.96217.36

Tunison, E., Sylvain, R., Sterr, J., Hiley, V., & Carlson, J. M. (2019). No money, no problem: Enhanced reward positivity in the absence of monetary reward. *Frontiers in Human Neuroscience,13*. doi:10.3389/fnhum.2019.00041

Ulrich, N., & Hewig, J. (2014). A miss is as good as a mile? Processing of near and full outcomes in a gambling paradigm. *Psychophysiology, 51*(9), 819–823. doi:10.1111/psyp.12232.

Van Holst, R. J., Chase, H. W., & Clark, L. (2014). Striatal connectivity changes following gambling wins and near-misses: Associations with gambling severity. *NeuroImage: Clinical, 5*, 232–239. doi:10.1016/j.nicl.2014.06.008.

Whitton, M., & Weatherly, J. N. (2009). The effect of near-miss rate and card control when American Indians and non-Indians gamble in a laboratory situation: The influence of alcohol. *American Indian and Alaska Native Mental Health Research, 16*(2), 28–42.

Wilkes, B. L., Gonsalvez, C. J., & Blaszczynski, A. (2010). Capturing SCL and HR changes to win and loss events during gambling on electronic machines. *International Journal of Psychophysiology, 78*(3), 265–272. doi:10.1016/j.ijpsycho.2010.08.008.

Wohl, M. J. A., & Enzle, M. E. (2003). The effects of near wins and near losses on self-perceived personal luck and subsequent gambling behavior. *Journal of Experimental Social Psychology, 39*(2), 184–191. doi:10.1016/S0022-1031(02)00525-5.

Worhunsky, P. D., Malison, R. T., Rogers, R. D., & Potenza, M. N. (2014). Altered neural correlates of reward and loss processing during simulated slot-machine fMRI in pathological gambling and cocaine dependence. *Drug and Alcohol Dependence, 145*, 77–86. doi:10.1016/j.drugalcdep.2014.09.013.

Wu, Y., Sescousse, G., Yu, H., Clark, L., & Li, H. (2018). Cognitive distortions and gambling near-misses in Internet Gaming Disorder: A preliminary study. *Plos One, 13*(1). doi:10.1371/journal.pone.0191110

Wu, Y., van Dijk, E., & Clark, L. (2015). Near-wins and near-losses in gambling: A behavioral and facial EMG study. *Psychophysiology, 52*(3), 359–366. doi:10.1111/psyp.12336.

Wu, Y., & Zhou, X. (2009). The P300 and reward valence, magnitude, and expectancy in outcome evaluation. *Brain Research, 1286*, 114-122. doi:10.1016/j.brainres.2009.06.032

Yeung, N., Holroyd, C. B., & Cohen, J. D. (2005). ERP Correlates of Feedback and Reward Processing in the Presence and Absence of Response Choice. *Cerebral Cortex, 15*(5), 535-544. doi:10.1093/cercor/bhh153

Zhou, Z., Yu, R., & Zhou, X. (2010). To do or not to do? Action enlarges the FRN and P300 effects in outcome evaluation. *Neuropsychologia, 48*(12), 3606-3613.

APPENDIX A

FIGURES

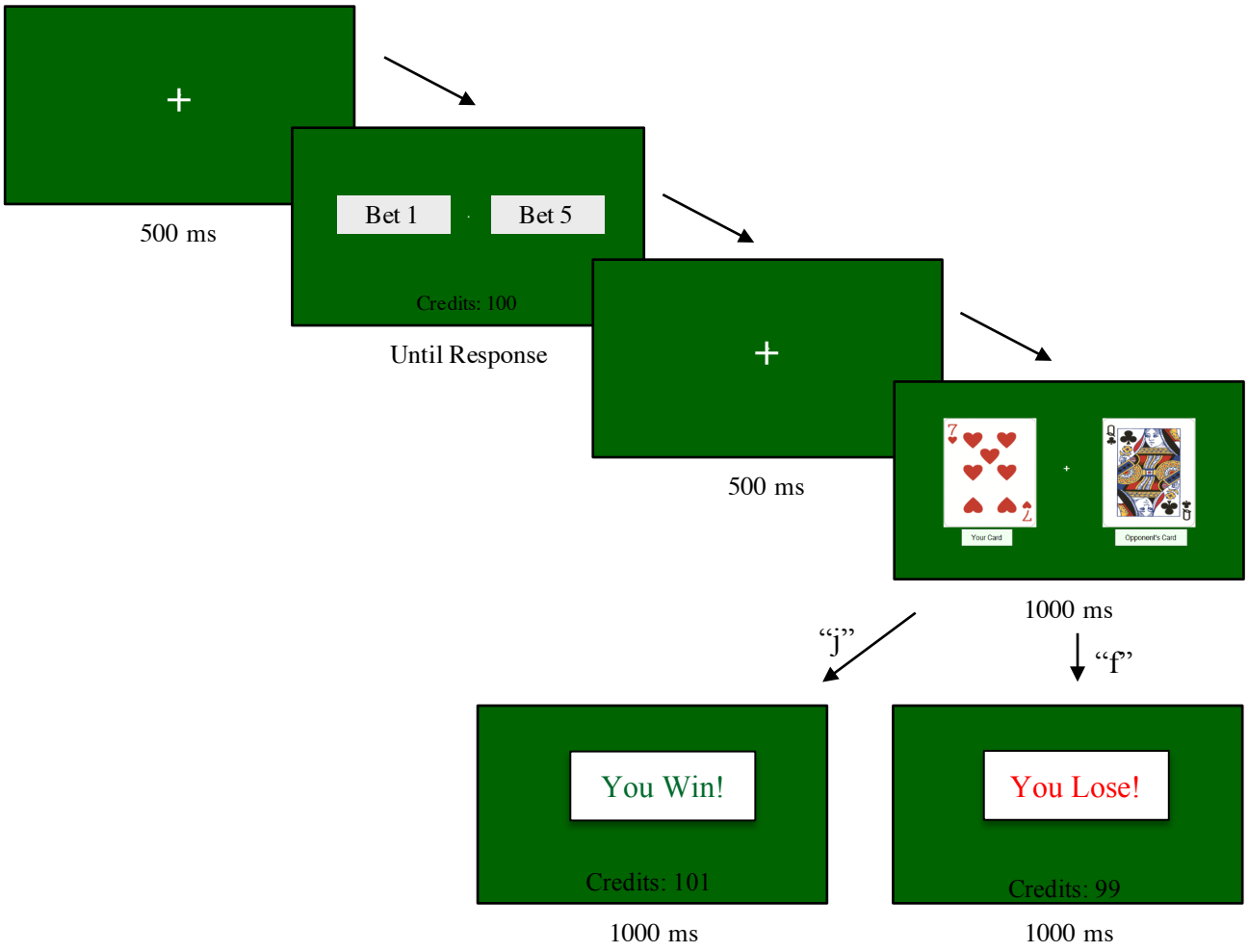

Figure 1. Shows a sample sequence of gameplay for the game of war card game used in the experiment. The "f" and "j" labels refer to whether the participant pressed the "f" or "j" key. All aspects not drawn to scale.

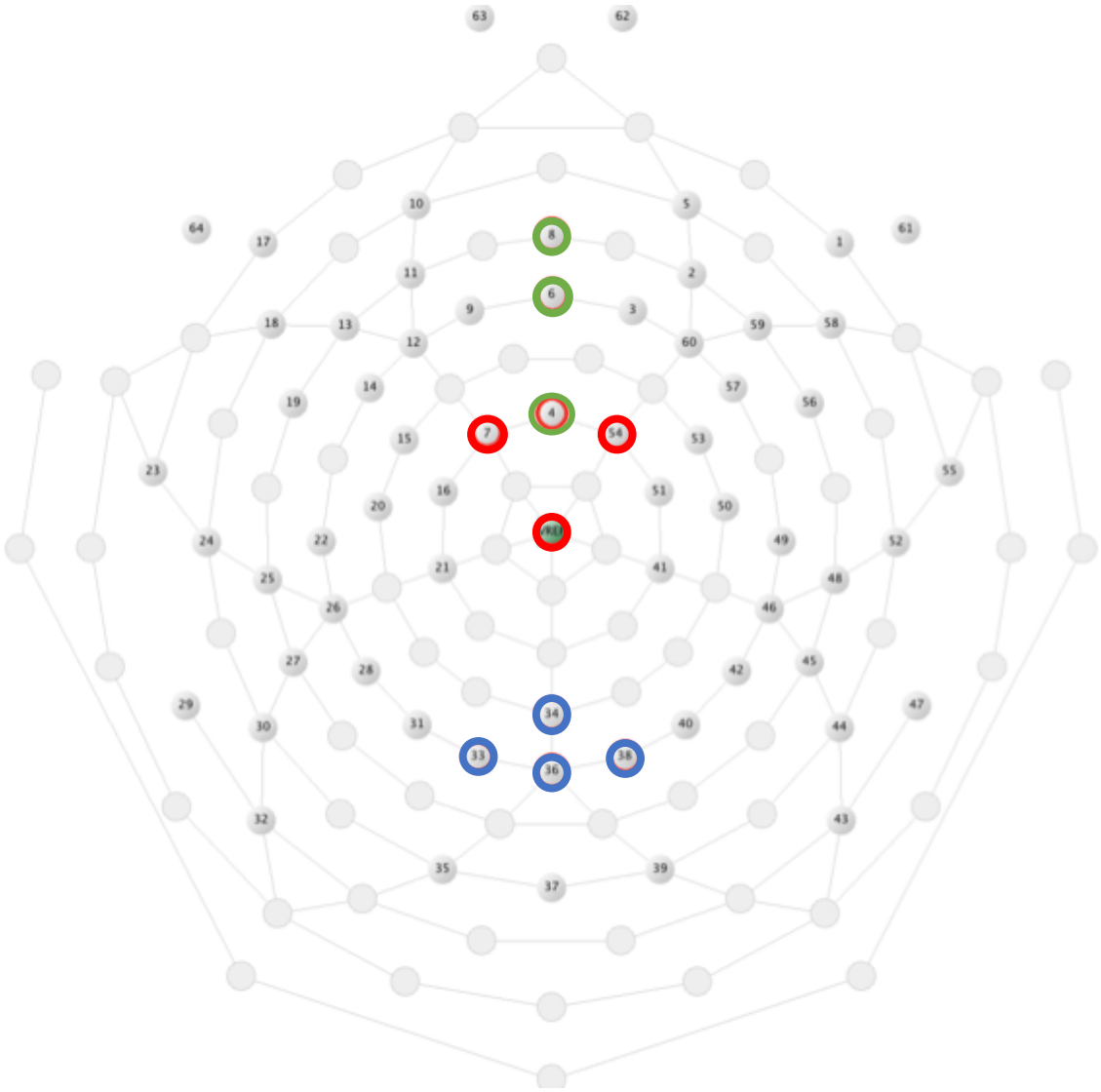

Figure 2. Shows the electrode layout used in the present study. Electrodes included in FRN analysis are indicated in green, P300 analysis in blue, and N1 and P2 analysis in red. One electrode, electrode 4, was used in both FRN and N1 and P2 analysis and is indicated with green and red.

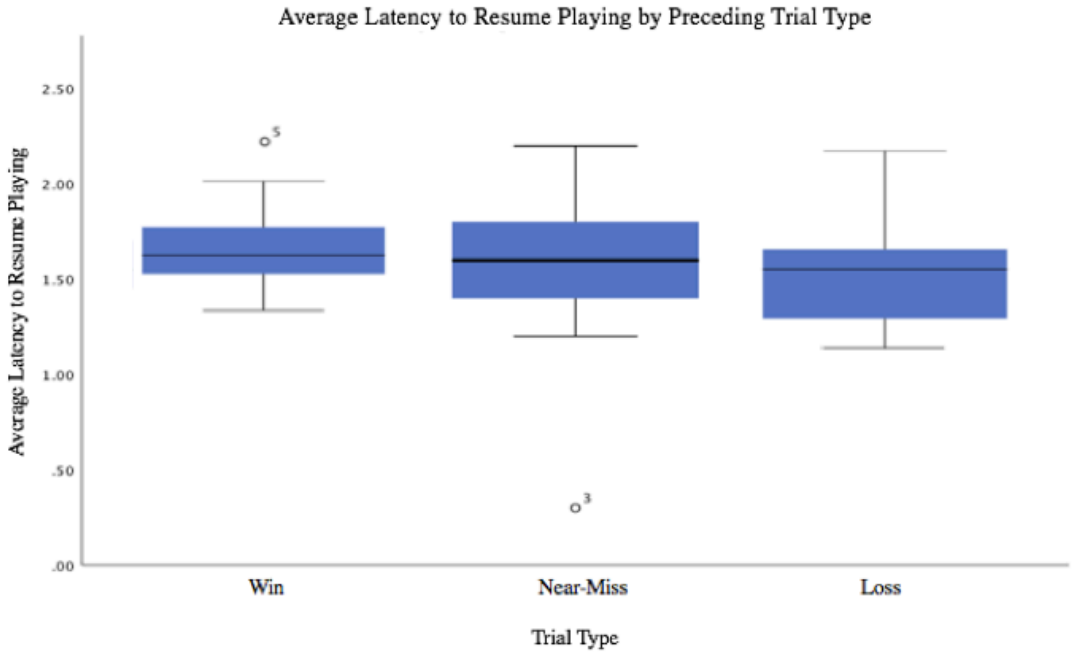

Figure 3. Shows the average latency to resume playing (in sec) following feedback presentation onset as a function of trial type.

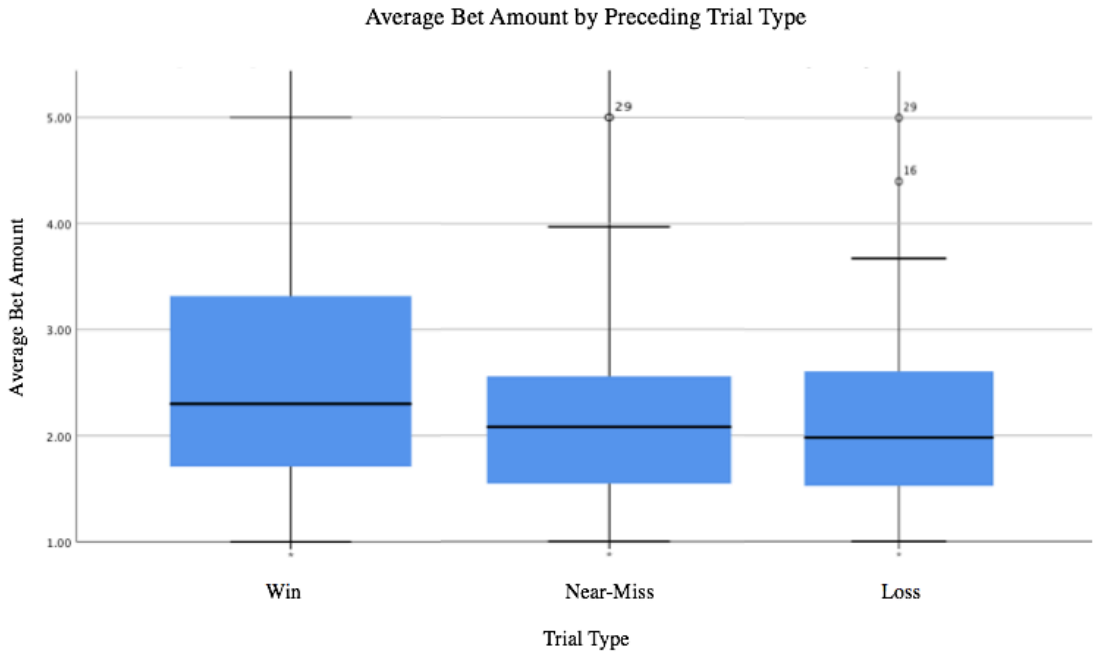

Figure 4. Shows the average bet amount placed as a function of the preceding trial type.

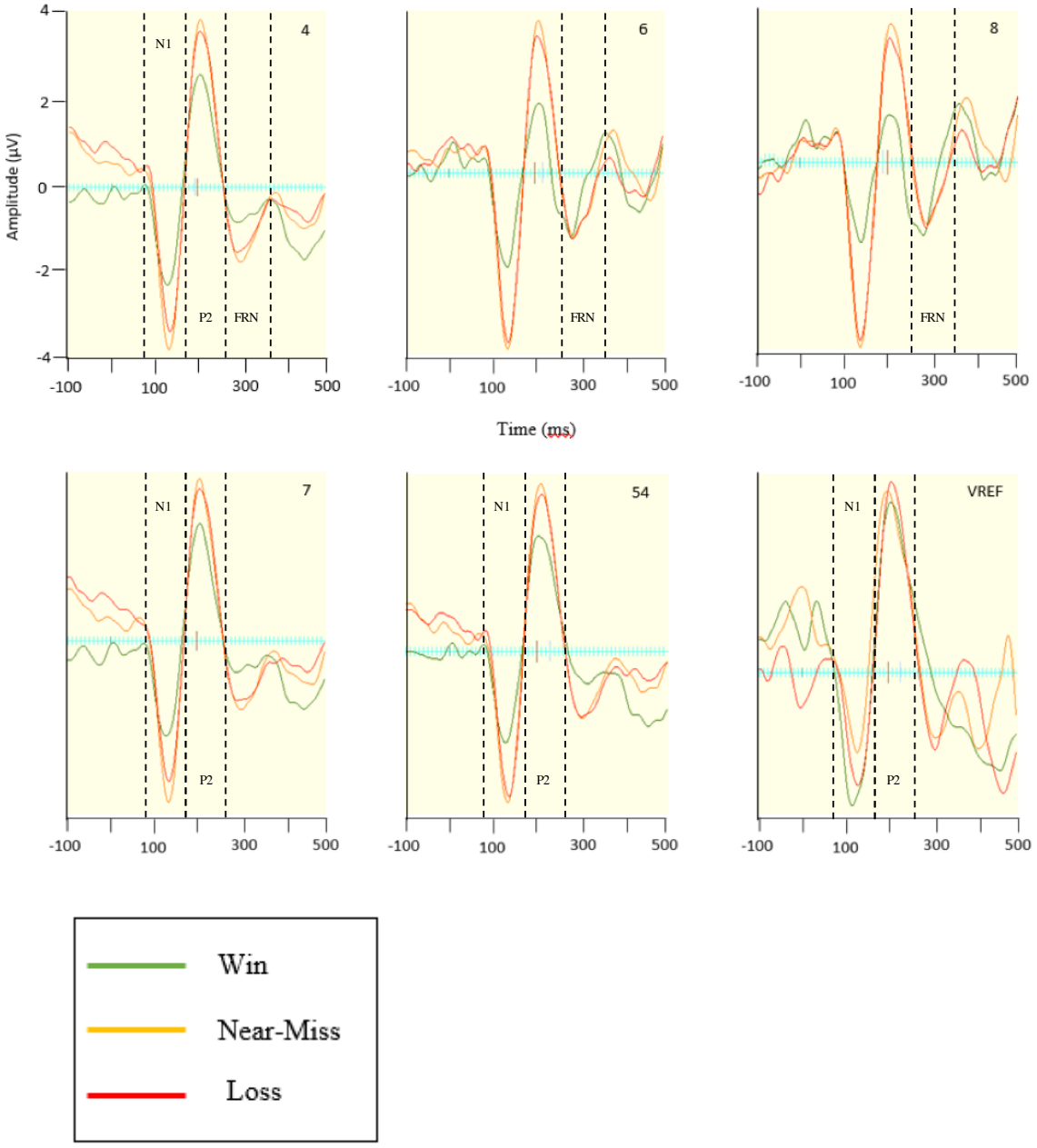

Figure 5. Shows grand averaged waveforms for each trial type at electrodes 4, 6 (Fz), and 8 for the FRN analysis and electrodes 4, 7, 54, and VREF (Cz) for the N1 and P2 analyses. The analyzed ERP components for each electrode are indicated between dotted lines.

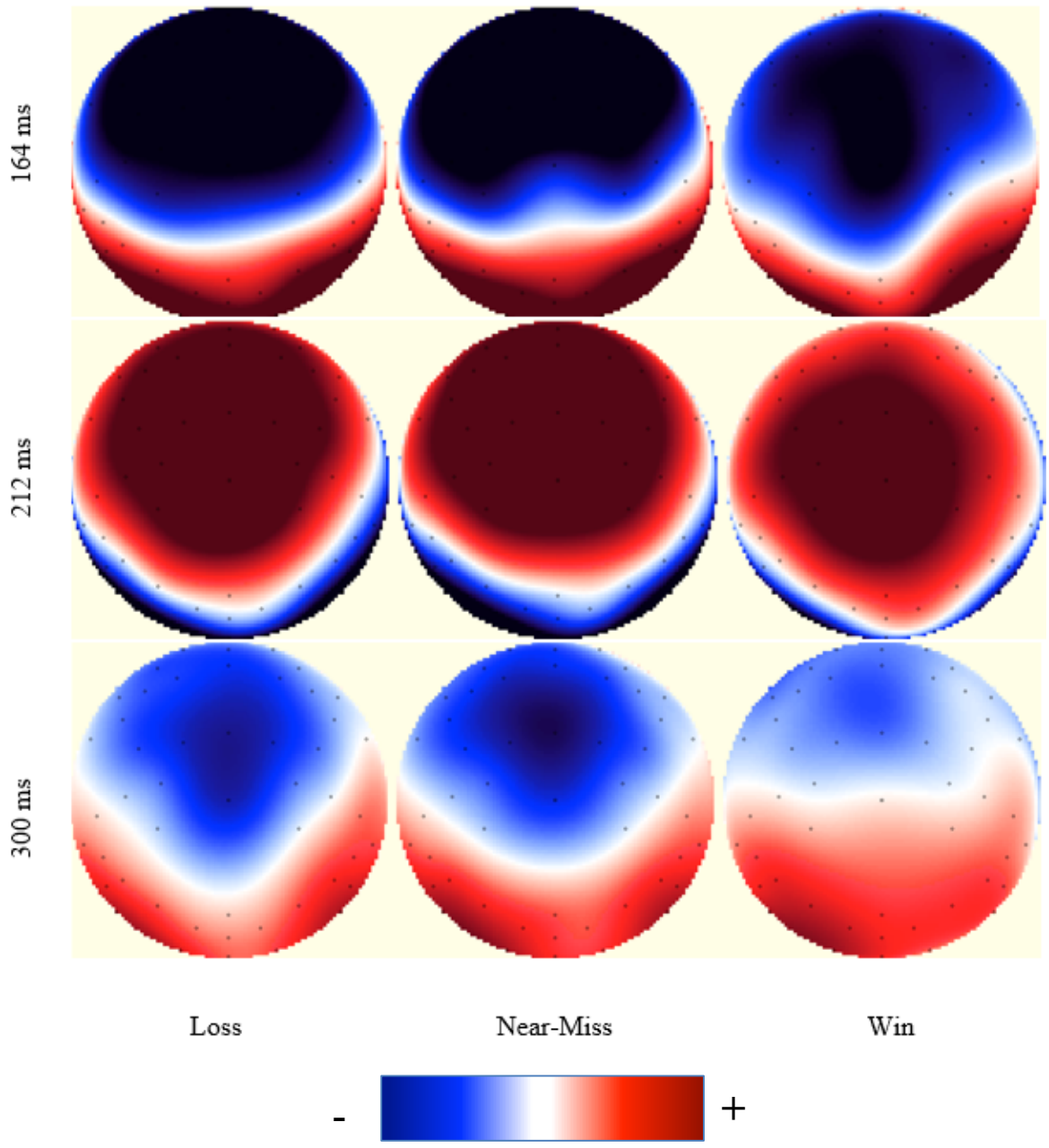

Figure 6. Shows topographical maps of grand averaged electrocortical activity as a function of trial type across all observed ERP time frames.

APPENDIX B

Human Subject Research Review Committee Approval

NORTHERN MICHIGAN UNIVERSITY

OFFICE OF GRADUATE EDUCATION AND RESEARCH
1401 Presque Isle Avenue
Marquette, MI 49855-5301
906-227-2300 | 906-227-2315
www.nmu.edu

MEMORANDUM

TO: Joshua Carlson
Psychological Sciences Department

CC: Jacob Daar
Psychological Sciences Department

FROM: Lisa Schade Eckert
Interim Dean of Graduate Education and Research

DATE: August 28, 2018

RE: Extension for IRB HS17-838
Original IRB Approval Date: 3/21/17
New Project Expiration Date: 8/28/19
"Neuroimaging measures of reward reactivity in simple and complex gambling tasks"

Your project modification to extend "Neuroimaging measures of reward reactivity in simple and complex gambling tasks" has been approved under the administrative review process. Please include your proposal number (HS17-838) on all research materials and on any correspondence regarding this project.

Any changes or revisions to your approved research plan must be approved by the IRB prior to implementation.

Please submit a Project Completion Form for Research Involving Human Subjects at the conclusion of your study.
If you do not complete your project within 12 months from the date of this approval notification, you must submit a Project Renewal Form for Research Involving Human Subjects. You may apply for a one-year project renewal a maximum of four times.

All forms can be found at the NMU Grants and Research website:
http://www.nmu.edu/grantsandresearch/node/102
If you have any questions, please contact the Office of Graduate Education and Research.