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Did I do that? The association between action video gaming experience and feedback processing in a gambling task

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A B S T R A C T

The association between action video game experience and the neural correlates of feedback processing related to positive and negative outcomes was examined in a virtual Blackjack game in combination with event-related brain potentials (ERPs). The behavioral data revealed that the frequency of various outcomes was not related to action gaming experience, indicating that the associations between action gaming experience and the ERP correlates of feedback processing are unlikely to result from variation in motivation or skill related to the Blackjack game between the gamers and non-gamers. The ERP data revealed that action gaming experience was not related to the processing of positive feedback related to wins, or negative feedback for losses that resulted from the joint action of the player and dealer. In contrast, action gaming experience was associated with a reduction in the amplitude of the ERPs elicited by negative feedback wherein the loss resulted from the direct action of the individual (i.e., busts). Together these data may indicate that action gaming is associated with a reduced sensitivity to feedback related to negative outcomes resulting from the direct action of the individual.

1. Introduction

Playing video games represents a ubiquitous form of entertainment beginning in childhood and continuing into adulthood. Action video games, wherein the player navigates a virtual world with the objective of killing enemies or destroying the resources of combatants, represent one of the most popular genres in the market (Entertainment Software Association, 2014). The influence of this genre of games on cognition, emotion, and social interaction has been the focus of intense investigation (see Anderson et al., 2010; Powers, Brooks, Aldrich, Palladino, & Alfieri, 2013). In an extensive meta-analysis of the perception and cognition literatures, Powers et al. demonstrated that action gaming has widespread effects on cognition as related to executive function, motor skill, spatial imagery, and visual processing. Additionally, there is some evidence that action gaming may be associated with an increase in risky decision-making. Bailey, West, and Kuffel (2013) reported that action gaming experience was associated with poor performance in the risk task that resulted from an increase in the number of risky choices made in the task, and this was accompanied by decreased sensitivity to feedback in the probabilistic selection task. In the current study, we sought to extend these findings by exploring the neural basis of the association between individual differences in action gaming experience and feedback processing in the context of risky decision-making by examining event-related brain potentials (ERPs) elicited during the performance of a virtual Blackjack game (West, Bailey, Tiernan, Boonsuk, & Gilbert, 2012).

1.1. Racing games and risky decision-making

While the relationship between action gaming and risky decision-making has not been widely considered, there is ample evidence demonstrating that experience with racing video games can affect risky decision-making. Racing video games appear to be particularly attractive to individuals predisposed to an increased risk of automobile accidents and deaths (National Highway Traffic Safety Administration, 2009), and the time spent playing racing games is associated with an increase in risky driving behavior and a decrease in cautious driving behavior in both adolescents and adults (Fischer, Kubitzki, Guter, & Frey, 2007). Complementing these individual difference data, laboratory studies demonstrate

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that playing a racing game can result in an increase in positive attitudes towards risk-taking and greater risk-taking behavior in a simulated driving task (Fischer et al., 2007, 2009). Furthermore, the effect of driving games on risk-taking appears to extend beyond the context of driving as recent evidence revealed that playing a racing game for 25 min decreased individuals interest in participating in a preventative health screening (Kastenmüller, Fischer, & Fischer, 2014). Together the limited evidence related to risky decision-making and action gaming, and the more extensive literature related to experience with racing games, indicates that gaining a clearer understanding of how experience with these media influences feedback processing related to risky decision-making could represent a valuable contribution to the literature.

1.2. ERPs and feedback processing

ERPs have been used extensively to study the neural correlates of feedback processing related to gains and losses in a variety of gambling and reinforcement learning paradigms (see Walsh & Anderson, 2012). The most commonly studied components represent transient neural activity over the medial frontal region that may originate from the anterior cingulate cortex (ACC; Gehring & Willoughby, 2002; Foti, Weinberg, Dien, & Hajcak, 2011). The feedback negativity (FN; Hajcak, Moser, Holroyd, & Simons, 2007) or feedback-related negativity (FRN; Walsh & Anderson, 2012; Gehring & Willoughby, 2002; Holroyd & Coles, 2002) represents a transient negativity over the frontal-central midline region that is greater in amplitude for losses than for gains around 300 ms after feedback is presented. The P2 or P2a (Holroyd, Pakzad-Vaezi, & Krigolson, 2008; Potts, Martin, Burton, & Montague, 2006) precedes the FN and reflects greater positivity for gains, particularly when unexpected, than for losses over the frontal-central midline region that peaks around 200 ms after feedback is presented. In the virtual Blackjack game used in the present study, the P2-FN-P3a component distinguishes two types of losses (i.e., losses and busts) from wins and ties (West et al., 2012, West, Bailey, Anderson, & Kieffaber, 2014). Losses result when the player's total is less than the total of the virtual dealer, and can be considered to arise from the joint action of the player and dealer. In contrast, busts result when the player's total exceeds 21, and can be considered to arise from the action of the player.

In addition to the P2-FN-P3a, there are sustained ERP components over the frontal, parietal, and occipital regions that are sensitive to feedback processing in the Blackjack game that have not been characterized in more simple gambling tasks. West, Bailey, Anderson, & Kieffaber (2014, 2012) have observed slow wave activity over the lateral frontal and parietal regions that distinguishes losses from wins and ties following the P2-FN-P3a. The lateral frontal slow wave activity may reflect recruitment within the inferior frontal gyrus or anterior temporal cortex, while the parietal slow wave activity appears to reflect activity within the posterior cingulate (West, Bailey, Anderson, & Kieffaber, 2014, West, Tiernan, Kieffaber, Bailey, & Anderson, 2014). These findings indicate that feedback processing represents a temporally extended process that can persist for 1500–2000 ms after feedback is delivered (West et al., 2012, West, Bailey, Anderson, & Kieffaber, 2014). This pattern of transient medial frontal and sustained lateral frontal and posterior neural activity associated with feedback processing is similar to conflict and error-related activity that has been associated with dynamic adjustments of cognitive control across trials in the color-word and counting Stroop tasks (Bailey, West, & Anderson, 2010; West & Travers, 2008). Drawing analogy from the cognitive control literature, West, Bailey, Anderson, & Kieffaber (2014, 2012) have suggested that this slow wave activity may reflect sustained processing associated with dynamic adjustments of information processing, which guides decision-making over time in the Blackjack game.

1.3. The current study

In the current study, we examined the relationship between action gaming experience and the ERP correlates of feedback processing related to four outcomes (i.e., ties, wins, losses, busts) in a virtual Blackjack game (West et al., 2012). This task was designed to simulate an engaging online gaming environment and allows one to measure ERPs associated with feedback processing related to gains (i.e., wins versus ties) and losses resulting from either the action of the player (i.e., busts) or the joint action of the player and a virtual dealer (i.e., losses). The inclusion of ties provides an opportunity to distinguish between the neural correlates of gains and losses that may be difficult to disentangle in gambling tasks wherein only binary outcomes (i.e., gains or losses) are represented (e.g., Gehring & Willoughby, 2002). Given evidence that action gaming experience may be associated with a reduction in reinforcement learning driven by positive and negative feedback (Bailey et al., 2013), we expected that there would be a reduction in the amplitude of transient medial frontal activity (i.e., P2-FN-P3a) and slow wave activity over the lateral frontal and posterior regions related to feedback processing that distinguishes wins, losses, and busts from ties. Based upon research examining the relationship between action gaming experience and affective information processing revealing both linear and non-linear associations between gaming experience and ERP amplitude (Bailey, West, & Anderson, 2011), we divided the action gamers into those with low, moderate, or high levels of experience. Partial Least Squares (PLS) Analysis (Lobaugh, West, & McIntosh, 2001) was used to analyze the ERP data. This method is well suited for identifying variation in the amplitude of ERP components related to the experimental design (i.e., that differ for wins, ties, losses and busts) and individual differences in action gaming experience across the full spatial-temporal distribution of the ERPs in a single analysis (McIntosh & Lobaugh, 2004).

2. Method

2.1. Participants

Ninety-eight male university students were recruited to participate in this study based on their responses to a media usage questionnaire, which they completed twice; once at least 2 weeks prior to participation in the laboratory session as part of a larger screening exercise, and once during the laboratory session. Individuals who reported spending two or fewer hours per week playing video games in the screening were recruited as low gamers. Individuals who reported spending ten or more hours per week playing video games and reported that they often or always played first-person shooter (i.e., action) video games in the screening were recruited as gamers. Data from twelve participants were excluded from the analyses due to misunderstanding how to play the Blackjack game (1), excessive artifact in the EEG data (1), a large (i.e., $\geq$5 h) increase or decrease in the number of hours reported playing video games per week between the initial screening and the laboratory session (5), or having fewer than five trials contribute to the ERP averages for one of the four outcomes (3), leaving 86 participants in the sample.

The dataset for the analyses included 70 individuals. In the 44 gamers, the median number of hours played per week was 20. Nineteen individuals played less than 20 h per week and were classified as moderate gamers ($M = 10$ h per week, $SD = 5$), and 25 individuals played 20 or more hours per week and were classified as high gamers ($M = 32$ h per week, $SD = 11$). Twenty-six of the 45 low gamers ($M = 0$ h per week) were randomly selected for the analyses (see Bailey et al., 2011 for a similar approach) in order to balance the size of the three groups.[2] The low gamers ($M = 20.62$, $SD = 5.29$), moderate gamers ($M = 18.68$, $SD = 0.75$), and high gamers ($M = 19.4$, $SD = 1.71$) were similar in years of age ($F(2,67) = 1.87$, $p = 0.16$) and in their distribution of handedness (non-gamers, right = 24, ambidextrous = 2; moderate gamers, right = 17, ambidextrous = 2; high gamers, right = 21, ambidextrous = 3, left = 1; $\chi^2(4, N = 70) = 2.15$, $p = 0.71$; Oldfield, 1971).

2.2. Materials

2.2.1. Media usage questionnaire

The media usage questionnaire included three higher order questions. Two questions asked the individual to indicate the number of hours spent playing video games on a typical weekday (Question 1, Monday through Friday) or weekend (Question 2, Saturday and Sunday) for each of four time periods (6 a.m. to noon, noon to 6 p.m., 6 p.m. to midnight, and midnight to 6 a.m.). The third question asked the participant to indicate how often he played each of 12 different genres of video games and what specific video game he spent the most time playing. The media usage questionnaire was administered during a screening session and during the laboratory session. For the full sample, the internal reliability was good for the number of hours played per week (screening coefficient $\alpha = 0.82$, laboratory session coefficient $\alpha = 0.82$) and the test-retest reliability of the measure was high ($r = 0.86$).

2.2.2. Blackjack game

The blackjack game was programmed in OpenGL (Silicon Graphics, Inc., Sunnyvale, CA) and was designed to look as if the participant was sitting at a casino table across from a dealer. Participants were instructed to make as much money as they could by getting their cards to equal more than the dealer's cards without going over 21. Participants were given \$1000 at the start of the game. A round of play (i.e., “hand”) consisted of three stages: betting, dealing, and feedback. In the betting stage, the participant placed a bet between \$50 and the total amount of money he currently held. In the dealing stage, the participant and dealer were dealt two cards. The participant then decided whether he would “hit” (receive another card) or if he would “stay” (keep the cards in hand). Feedback (i.e., “You win”, “You lose”, or “Push” – indicating a tie – and total money) was displayed after the participant selected to stay or if the participant's cards equaled more than 21 (i.e., a “bust” or loss). To increase his bet and to “hit” participants pressed the “m” key and to decrease this bet or to “stay” participants pressed the “v” key. The spacebar was used to advance from the betting stage to the dealing stage and to advance from the feedback to the next hand. After instructions were given, participants practiced the game for 5 min. EEG data were recorded for 15 min of play. If the participant reached a balance of \$0 before the end of that time, then the game was reset and he continued playing.

[2] We had initially planned to examine differences between non-gamers and action gamers, hence the collection of roughly equal numbers of individuals from these two groups. However, as other evidence from our laboratory had revealed non-linear effects of gaming experience (Bailey et al., 2011; 2013) we decided to consider low, moderate, and high gamers at the time of data analysis. Therefore, 26 of the 45 low gamers were randomly selected for the analyses presented in the paper.

2.3. Procedure

Upon arriving at the laboratory, the fitting of the Electro-cap (Electro-cap International, Easton, OH) was described to the participant and written informed consent was obtained. The participant completed the media usage questionnaire, Edinburgh Handedness Inventory, and several other questionnaires not relevant to the current study. After the cap was fitted, the participant was moved to the testing room and seated in front of the computer monitor. Participants were asked to limit eye and head movements during recording. All of the participants played blackjack for 15 min; half of the participants also completed three additional tasks (probabilistic selection, the risk task, and the useful field of view task), the results of which will not be reported here. Following testing, the participants were debriefed.

2.4. Electrophysiological recording and analysis

The electroencephalogram (EEG) (bandpass 0.02–150 Hz, digitized at 500 Hz, gain 1000, 16-bit A/D conversion) was recorded from an array of 68 tin electrodes based on a modified 10–20 system using an Electro-cap (Electro-Cap International, Eaton, OH). Vertical and horizontal eye movements were recorded from electrodes placed beside and below the right and left eyes. During recording all electrodes were referenced to electrode Cz, then re-referenced to an average reference for data analysis. A 0.1–12 Hz zero phase shift bandpass filter was applied to the data. Ocular artifacts associated with blinks and saccades were removed using the Ocular Artifact Correction filter in EMSE (Source-Signal Imaging, San Diego). ERPs were averaged for bust, losses, wins, and ties from −200 to 2000 ms around feedback onset with a baseline of −200 to 0 ms. Five subjects (three non-gamers, one moderate gamer, one high gamer) with fewer than five trials contributing to the ERP averages for at least one of the four outcomes were dropped from the analyses. The average number of trials contributing to the ERP averages for the outcomes was: wins $M = 54$ (range 12–100), losses $M = 33$ (range 10–71), busts $M = 42$ (range 8–80), and ties $M = 13$ (5–64).

Given the widespread distribution of the ERPs related to feedback processing across the scalp and the duration of the slow wave activity, the data were analyzed using PLS analysis (Lobaugh et al., 2001) with the ERP module of the PLSGUI (www.rotman-baycrest.on.ca/pls/). PLS analysis provides an efficient method of identifying and testing the reliability of effects of group membership and experimental design over the full spatial-temporal distribution of an ERP dataset (McIntosh & Lobaugh, 2004). To reduce the computational demands of the PLS analysis the ERP data were down sampled to 100 Hz using Matlab 7.12. The analysis included the ERPs from 0 to 2000 ms after feedback onset at 64 electrodes excluding the four ocular electrodes. A permutation test (500 samples) was used to establish the statistical significance of the latent variables. Bootstrap resampling (500 samples) was used to examine the reliability of the brain scores – that represent the strength of a latent variable for each group and outcome – and electrode saliences – that represent the expression of the latent variables over time and space (i.e., electrodes). The 95% confidence intervals from the bootstrap resampling are reported for the brain score contrast and the electrode saliences threshold was set at ≥ 2.0, roughly $p = 0.05$.

3. Results

3.1. Behavioral data

The behavioral data for the study are presented in Table 1. A one-way ANOVA was used to examine the effect of action gaming on the

Table 1
Means and standard deviations for the behavioral data by gaming status.

		Non-gamers	Moderate	High
Sample size		26	19	25
Average bet	M	144.19	123.53	103.08
	SD	80.43	116.82	47.34
Total score	M	−369.23	−910.53	−54.00
	SD	1791.43	1622.80	1677.23
Bust	M	0.28	0.29	0.30
	SD	0.11	0.05	0.07
Loss	M	0.24	0.23	0.22
	SD	0.09	0.05	0.07
Win	M	0.37	0.40	0.39
	SD	0.09	0.03	0.06
Tie	M	0.08	0.09	0.08
	SD	0.03	0.02	0.02

average bet and total score. The main effect was not significant in either analysis (average bet $F(2, 67) = 1.57$, $p = 0.11$, $\eta_p^2 = 0.05$, total score $F(2, 67) = 1.37$, $p = 0.26$, $\eta_p^2 = 0.04$). A 3 (Gaming status) x 4 (Outcome) ANOVA was used to examine the effect of gaming status on outcome. The main effect of gaming status was not significant, $F(2, 67) = 0.84$, $p = 0.44$, $\eta_p^2 = 0.03$, and the main effect of outcome was significant, $F(3, 201) = 263.03$, $p < 0.001$, $\eta_p^2 = 0.80$, with the frequency of the outcome increasing from ties to losses, $t(69) = 16.81$, $p < 0.001$, from losses to busts, $t(69) = 3.87$, $p < 0.001$, and from busts to wins, $t(69) = 8.44$, $p < 0.001$ (Bonferroni corrected $p < 0.017$).

3.2. ERP data

The grand-averaged ERPs for the four outcomes in the three groups at nine electrodes are presented in Fig. 1. These data reveal ERPs that were sensitive to feedback processing in the Blackjack game similar to those observed in our previous research using this paradigm (West, Bailey, Anderson, & Kieffaber, 2014, 2012). At a descriptive level, the ERPs express the P2-FN-P3a over the midline frontal region and slow wave activity over the left lateral frontal and posterior regions. There appear to be some differences in the amplitude of the medial frontal ERPs between the three groups of subjects; in contrast, differences in the amplitude of slow wave activity between negative outcomes (busts and losses) and wins and ties are clearly reduced in the high gamers relative to the non-gamers or moderate gamers. The permutation test for the PLS analysis revealed three significant latent variables ($p < 0.001$, $p < 0.001$, $p = 0.002$) that accounted for (62.32%, 16.33%, 8.15%) of the covariance between the four outcomes across the three groups.

The first latent variable contrasted busts with ties and wins across the three groups, in addition to busts and losses in the moderate gamers (Figs. 2–3, Table 2). Based upon the 95% confidence intervals for the brain scores, the strength of the effect was similar in the low gamers and moderate gamers, and was reduced in high gamers relative to the low gamers and moderate gamers (Table 2). The bootstrap test for the electrode saliences revealed stable time points over much of the analyzed epoch. These corresponded to the timing of the P2-FN-P3a over the frontal-central region (Fig. 2 FCz), the P3b and slow wave activity over the parietal region (Fig. 2 Pz), and transient and slow wave activity over the left lateral frontal and occipital regions (Fig. 2 F9/Oz). These findings indicate that processing feedback related to losses that resulted from the action of the player (i.e., busts) was attenuated in the high action gamers relative to the low gamers or moderate gamers. This latent variable is consistent with the hypothesis that action gaming experience would be associated with a reduction in transient medial frontal activity and slow wave activity over the lateral frontal and posterior regions.

The second latent variable contrasted losses with ties across the three groups (Figs. 2 and 3). For the low gamers the brain scores for wins and busts also differed from zero (Fig. 2). Based upon confidence intervals, the strength of the effect for losses appears to be weaker for moderate gamers than for low or high gamers. However, the absolute difference between in the brain scores for losses and ties was similar across the groups so it does seem that strength of the effect is particularly sensitive to action gaming experience (Table 2). The bootstrap test revealed stable electrode saliences between 100 and 1000 ms after onset of the feedback that corresponded to the P2-FN-P3a over the frontal-central region (Fig. 2b FCz), early transient activity followed by more sustained activity over the occipital region (Fig. 2b Oz), and sustained activity over the left lateral frontal region (Fig. 2b F9). In contrast to the first latent variable, the P3b did not appear to contribute to the second latent variable given the lack of reliable electrode saliences over the parietal region (Fig. 2b Pz). Together the pattern of stable electrode saliences for the first and second latent variables indicates that P2-FN-P3a, and left frontal slow wave are generally sensitive to negative outcomes, while the P3b may be more sensitive to negative outcomes that result from the action of the individual (first latent variable) than the combined action of the individual and the virtual dealer (second latent variable).

The third latent variable contrasted wins and ties in the low gamers and the high gamers (Figs. 2 and 3); in contrast, for moderate gamers the brain scores for wins and losses differed from zero. Across the three groups the size of the brain scores for wins was similar and the 95% confidence intervals were overlapping, indicating that feedback processing related to wins may be relatively insensitive to action gaming experience in this task. The bootstrap test revealed stable electrode saliences over the frontal-central region (Fig. 2 FCz), the left lateral frontal region between 500 and 1000 ms (Fig. 2 F9), and the parietal and occipital regions (Fig. 2 Pz/Oz).

4. Discussion

In this study we examined the association between action gaming experience and the neural correlates of feedback processing related to risky decision-making in a virtual Blackjack game. The ERP data revealed that feedback processing was associated transient medial frontal neural activity (i.e., P2-FN-P3a), and slow wave activity over the parietal (i.e., P3b and slow wave), lateral frontal, and occipital regions. These findings converge with the results of previous research using this paradigm to examine the neural correlates of feedback processing (West et al., 2012), and are consistent with the functional neuroimaging literature demonstrating that feedback processing is associated with a distributed network involving cortical and subcortical structures (Liu, Hairston, Schrier, & Fan, 2011). Action gaming was associated with a reduction in the amplitude of transient medial frontal and sustained lateral frontal and posterior ERPs that distinguished busts from ties and wins (i.e., first latent variable). In contrast, neural activity that distinguished the processing of losses or wins from the other outcomes (i.e., second and third latent variable) appeared to be relatively insensitive to action gaming experience. These findings may reveal a specific association between action gaming experience and feedback processing, wherein high levels of gaming (i.e., >20 h per week) was related to a decreased sensitivity to negative feedback resulting from one's actions, rather than a more general attenuation of feedback processing for positive and negative outcomes.

4.1. Behavioral data

The behavioral data revealed that the frequency of the four

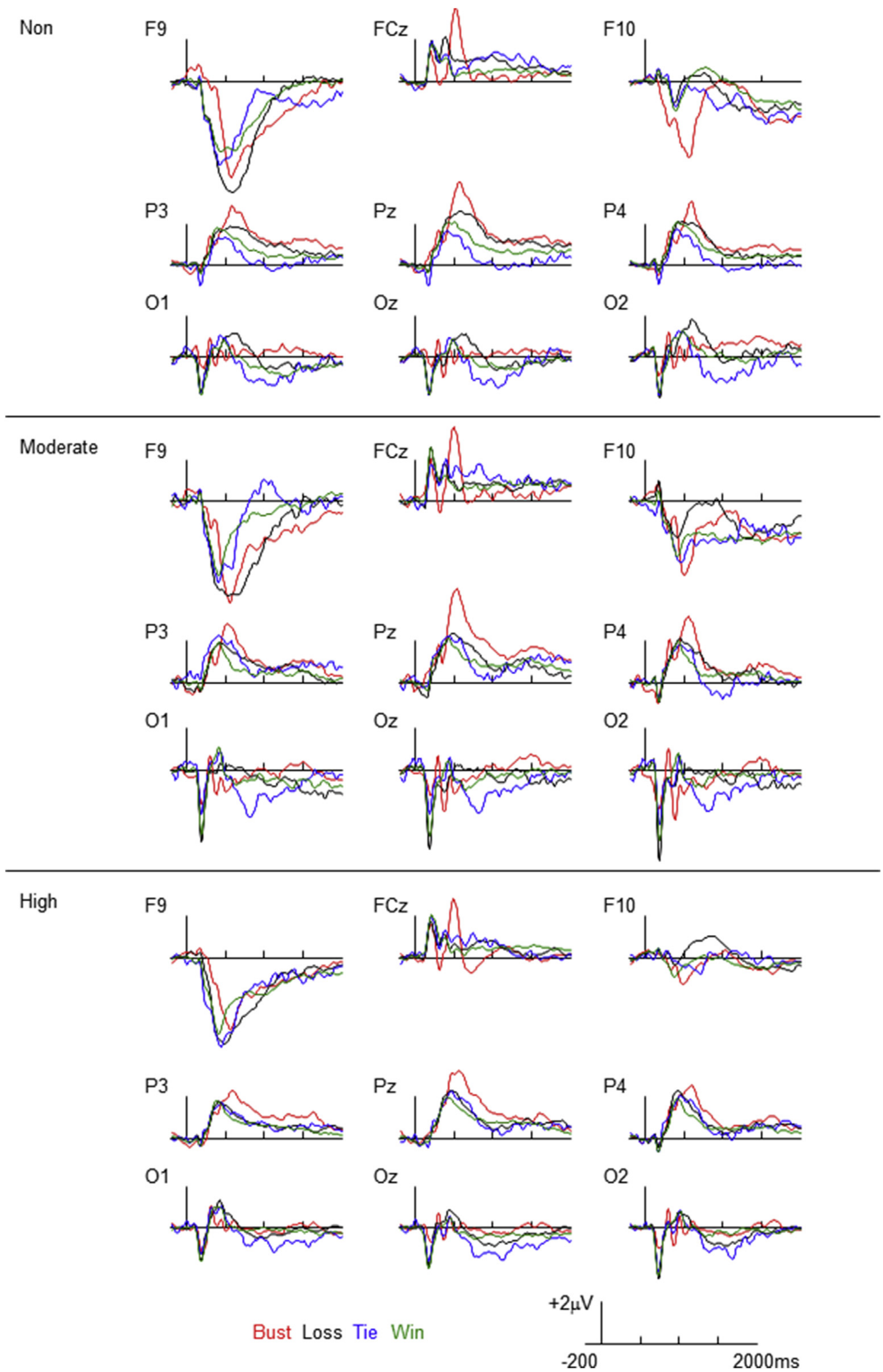

Fig. 1. Grand-averaged ERPs at nine electrodes in non-gamers, moderate gamers and high gamers for the four outcomes of a hand in the Blackjack game. The tall bar represents onset of the feedback, the short bars represent 500 ms increments, and positive is plotted up.

outcomes was similar across the three gaming groups. This finding indicates that differences in the neural correlates of feedback processing for busts related to action gaming experience did not simply reflect variation in the probability of the outcomes across groups. The high gamers tended to bet less and lost less than the non-gamers and moderate gamers, although group differences in these variables were not significant, possibly resulting from the high degree of variability in betting within the sample.

4.2. Processing negative feedback

Two of the latent variables represented the neural correlates of

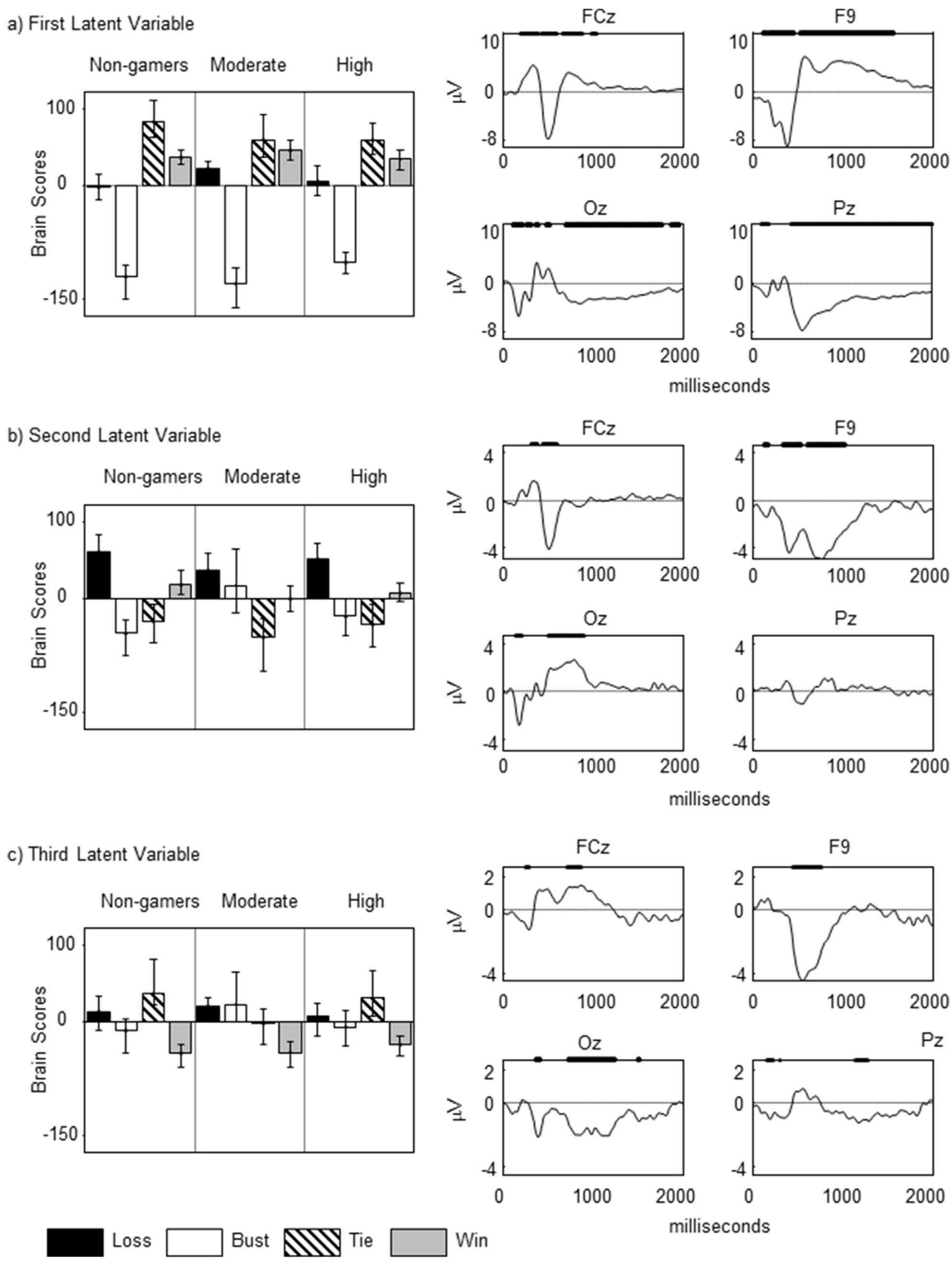

Fig. 2. Brain scores portraying the contrasts for the three reliable latent variables and electrode saliences at four representative electrodes for each latent variable from the PLS analysis. The confidence intervals for the brain scores represent the 95% confidence interval from the bootstrap test. The "o" above at the top of the plots demonstrate time points where the electrode saliences differed from zero (i.e., bootstrap ratio ≥ 2.0).

Table 2
Brain scores and 95% confidence intervals for the three significant latent variables from the PLS analysis.

	Loss	Bust	Tie	Win
First LV				
Non-gamers	−1 [−19, 16]	−119 [−149, −103]	83 [63, 111]	38 [28, 46]
Moderate gamers	22 [14, 32]	−129 [−161, −109]	60 [36, 93]	46 [34, 60]
High gamers	6 [−13, 26]	−100 [−116, −87]	60 [41, 81]	34 [21, 47]
Second LV				
Non-gamers	60 [49, 83]	−47 [−76, −28]	−31 [−59, −8]	18 [5, 36]
Moderate gamers	36 [20, 58]	16 [−19, 65]	−52 [−26, −96]	−1 [−17, 16]
High gamers	52 [38, 71]	−24 [−50, 0]	−34 [−61, −8]	6 [−5, 20]
Third LV				
Non-gamers	14 [−11, 33]	−11 [−41, 3]	38 [22, 83]	−41 [−60, −29]
Moderate gamers	20 [7, 31]	23 [0, 65]	−2 [−30, 16]	−40 [−59, −27]
High gamers	7 [−18, 23]	−7 [−33, 14]	30 [8, 67]	−30 [−44, −180]

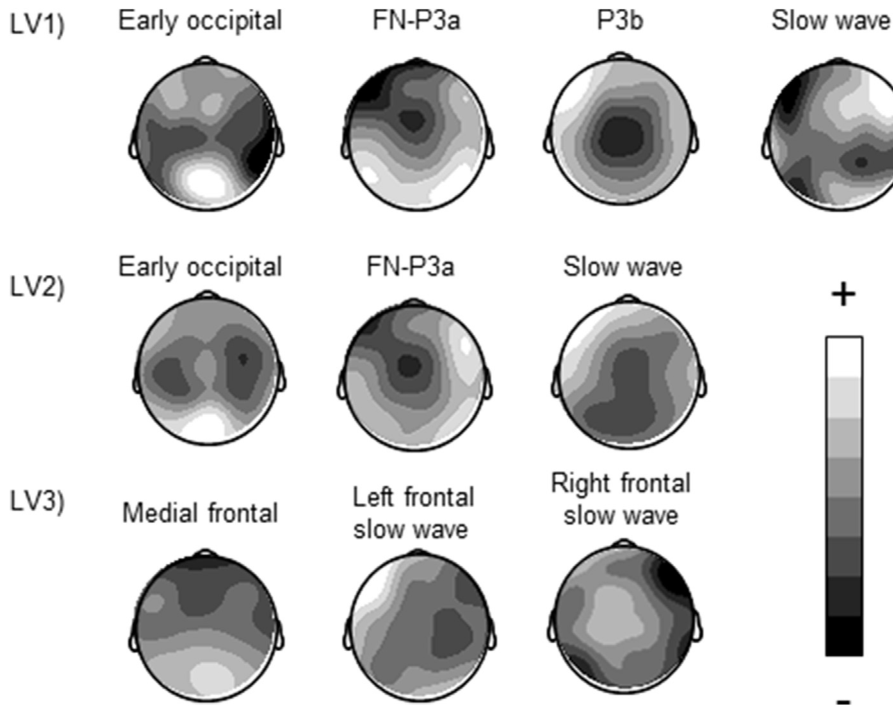

Fig. 3. 2D Topography maps portraying the distribution of the electrode saliences at select epochs for the three significant latent variables. The individual maps are scaled to demonstrate the distribution of relevant component(s); therefore, comparisons between maps should be relative rather than absolute as related to amplitude.

processing negative feedback. The first and second latent variables captured the ERP correlates of feedback processing that was primary related to busts or losses, respectively. Both of these latent variables include the P2-FN-P3a, and feedback processing for busts was additionally associated with the P3b. Our data converge with other evidence demonstrating a dissociation between the P2-FN-P3a and P3b (West, Bailey, Anderson, & Kieffaber, 2014; Yeung & Sanfey, 2004). These data, together with the findings related to the third latent variable associated with processing positive feedback, indicate that the P2-FN-P3a is generally associated with the coding of negative outcomes in the Blackjack game and other tasks (Walsh & Anderson, 2012). In contrast, our findings lead to the suggestions that the neural generators of the P3b may be differentially involved in the processing of feedback associated with negative outcomes that result from the action of the individual (i.e., busts) relative to negative outcomes that result from the action or inaction of the individual and the virtual dealer (West, Bailey, Anderson, & Kieffaber, 2014). The P3b may be associated with the activity of a neural system involving the locus coerulus and posterior cingulate that codes the motivational significance of stimuli (Nieuwenhuis, 2011), and our data may indicate that this system is particularly sensitive to negative outcomes resulting from one's own actions.

The association between action gaming and feedback processing for negative outcomes differed for busts and losses as revealed in the first and second latent variables. For the second latent variable, the strength of the contrast between losses and ties was similar across the three groups. In contrast, for the first latent variable the strength of the contrast was weaker for busts in high gamers than in low gamers or moderate gamers. This finding indicates that high levels of action gaming may be associated with reduced processing of negative outcomes attributable to one's own actions. The dose dependent nature of the association between action gaming and feedback processing related to busts converges with work examining the relationship between action gaming and both affective information processing (Bailey et al., 2011) and risky decision-making (i.e., similar responding for low gamers and moderate gamers, and a diminished response for high gamers; Bailey et al., 2013). Together these finding lead to the suggestion that higher levels of action gaming experience may be particularly problematic. The reason(s) for the dose dependent influence of action gaming remains unclear based upon the available evidence. There is a positive correlation between hours spent gaming and the presence of pathological gaming (Bailey et al., 2013). So one possibility is that pathological gamers were more heavily represented in our sample of high gamers than in our sample of moderate gamers, with the presence of pathological gaming and action gaming interacting to produce the negative association between action gaming and feedback processing related to busts.

The reduction in the amplitude of transient medial frontal and sustained lateral frontal and posterior ERP activity associated with action gaming experience in the first latent variable is consistent with data reported by Bailey et al. (2010) for the Stroop task. Bailey et al. reported that the amplitude of the medial frontal negativity and slow wave activity was attenuated in action gamers relative to low gamers. These data reveal a striking convergence in the association between action gaming experience and ERP activity in two tasks that have very different information processing demands, leading to the suggestion that this pattern may reflect a core attribute of action gaming experience. Cavanagh and Frank (2014) argue that medial frontal Theta activity, which likely contributes to the P2-FN-P3a, serves to signal the need for cognitive control. This idea is consistent with theories linking recruitment of the ACC to the generation of a control signal that supports the tuning of cognitive control over time (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Braver, 2012). Lateral frontal and posterior slow wave ERP activity following transient medial frontal activity has been linked to adaptive processing related to both conflict detection (Bailey et al., 2010) and error monitoring (West & Travers, 2008). By extension then, the slow wave activity observed in the

Blackjack task could be related to adaptive processing across hands in the game that is attenuated with increasing action gaming experience. Given the lack of group differences in the behavioral measures, further research is required to determine how this is manifest in behavior.

4.3. Processing positive feedback

The third latent variable captured neural activity that distinguished feedback processing for wins relative to ties for the low gamers and high gamers, and losses in the moderate gamers, and may therefore reflect the neural correlates of processing positive feedback. Consistent with the existing literature, this latent variable reflected transient activity over the medial frontal region that could include the P2 described in previous studies (Holroyd et al., 2008; Potts et al., 2006). This latent variable also revealed reliable electrode saliences over the left lateral frontal and parietal and occipital region that has not been characterized in previous ERP studies of the neural correlates of processing positive feedback. Similarities between the distribution of the electrode saliences for the three latent variables that represented feedback processing for positive and negative outcomes may reveal a relatively generic feedback processing system that supports the processing of gains and losses relative to neutral outcomes (i.e., ties; Liu et al., 2011).

For the third latent variable, the size of the brain scores for wins was similar across the three groups, leading to the suggestion that the processing of positive feedback was relatively insensitive to action gaming experience. This finding is consistent with the results of our previous work examining the relationship between action gaming and affective picture processing (Bailey et al., 2011), wherein ERP activity related to processing pictures with positive valence was similar in low gamers and action gamers. Together, these findings may indicate that action gaming does not have a general effect on the processing of stimuli with positive valence. The current findings are inconsistent with behavioral (Kirsh & Mounts, 2007) and electrophysiological (Bailey & West, 2013) evidence demonstrating that processing positive affect represented in the face is attenuated by acute and chronic exposure to action or violent video games. Therefore, in combination the available evidence indicates that it may be important to consider the content area or stimulus domain when drawing conclusions related to the influence of action gaming on the processing of positive valence.

4.4. Limitations

There are some limitations of the current study that must be considered. First, the association between action gaming and feedback processing was examined at the individual difference level. This makes it impossible to know whether the relationship between action gaming and feedback processing reflects a direct effect of gaming experience or some third variable that influences both interest in action gaming and the processing of negative feedback related to one's actions. Given the known causal effects of action video games on performance across a wide range of tasks assessing emotion and cognition (Anderson et al., 2010; Powers et al., 2013), it seems reasonable to assume that at least part of the association between action gaming and feedback processing observed in the current sample could reflect a causal influence. Second, given the focus on action gaming it is impossible to know whether the association with feedback processing is specific to this game genre or would extend to other genres. Bailey et al. (2013) reported some differences in the association between action gaming and strategy gaming as related to behavioral measures of feedback processing and risky decision-making, so further investigation of the association between other gaming genre's and feedback processing could be a valuable pursuit. Additionally, the participants were recruited based on their experience with action video games, which are different in many regards from the gambling task used in the current study. Based on the data from racing video games (Fischer et al., 2007, 2009), certain genres of games may have specific effects on closely associated behaviors (e.g., risky driving in the video game increases risky driving in a simulator/real-world). It will be important for future work to disentangle the specific effects of different video game genres on tasks with varying degrees of similarity to the game context. Third, the current study was not designed to examine the possible interaction between action gaming and pathological gaming that might be relevant to the association between action gaming and feedback processing related to busts. This issue might be addressed in a larger scale study that systematically sampled pathological and non-pathological action gamers. Fourth, given the naturalistic nature of game play in the Blackjack game it was not possible to control the absolute or relative frequency of the four outcomes resulting in some subjects having low trial counts for some outcomes, particularly ties. The ERPs elicited by ties were similar to those elicited by these trials in a previous study in terms of wave shape and ordering relative to the other outcomes (West et al., 2012), this leads us to believe that the ERPs elicited by ties and the contribution of this outcome to the latent variables is likely to be robust.

4.5. Conclusions

The current study revealed a specific association between action gaming experience and feedback processing wherein the amplitude of ERPs related to processing feedback related to negative outcomes attributable to one's action were attenuated in individuals with high levels of action gaming experience. In contrast, ERPs related to processing positive outcomes or negative outcomes reflecting the joint action of the player and dealer appeared to be insensitive to action gaming experience. The negative association between high levels of action gaming experience the transient and sustained ERP activity elicited during feedback processing for busts, converges with data reported by Bailey et al. (2010) related to proactive cognitive control leading to the suggestion that this may represent a general outcome of higher levels of action gaming experience.

References

Anderson, C. A., Shibuya, A., Ihori, N., Swing, E. L., Bushman, B. J., Sakamoto, A., et al. (2010). Violent video game effects on aggression, empathy, and prosocial behavior in Eastern and Western countries. *Psychological Bulletin, 136*, 151–173. http://dx.doi.org/10.1037/a0018251.

Bailey, K., & West, R. (2013). The effects of an action video game on visual and affective information processing. *Brain Research, 1504*, 35–46. http://dx.doi.org/10.1016/j.brainres.2013.02.019.

Bailey, K., West, R., & Anderson, C. A. (2010). A negative association between video game experience and proactive cognitive control. *Psychophysiology, 47*, 34–42. http://dx.doi.org/10.1111/j.1469-8986.2009.00925.x.

Bailey, K., West, R., & Anderson, C. A. (2011). The association between chronic exposure to video game violence and affective picture processing: An ERP study. *Cognitive Affective & Behavioral Neuroscience, 11*, 259–276. http://dx.doi.org/10.3758/s13415-011-0029-y.

Bailey, K., West, R., & Kuffel, J. (2013). What would my avatar do? Gaming, pathology, and risky decision making. *Frontiers in Psychology, 4*, 1–10. http://dx.doi.org/10.3389/fpsyg.2013.00609.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review, 108*, 624–652. http://dx.doi.org/10.1037//0033-295X.I08.3.624.

Braver, T. S. (2012). The variable nature of cognitive control: A dual mechanisms framework. *Trends in Cognitive Sciences, 16*, 106–113. http://dx.doi.org/10.1016/j.tics.2011.12.010.

Cavanagh, J. F., & Frank, M. J. (2014). Frontal theta as a mechanism for cognitive control. *Trends in Cognitive Sciences, 18*, 414–421. http://dx.doi.org/10.1016/j.tics.2014.04.012.

Entertainment Software Association. (2014). Retrieved March 3, 2014, from http://www.theesa.com/facts/salesandgenre.asp.

Fischer, P., Greitemeyer, T., Morton, T., Kastenmuller, A., Postmes, T., Frey, D., Kubitzki, J., & Odenwalder, J. (2009). The racing-game effect: Why do video racing games increase risk-taking inclinations? *Personality and Social Psychology Bulletin, 35*, 1395–1409. http://dx.doi.org/10.1177/0146167209339628.

Fischer, P., Kubitzki, J., Guter, S., & Frey, D. (2007). Virtual driving and risk taking: Do racing games increase risk-taking cognitions, affect, and behaviors? *Journal of Experimental Psychology: Applied, 13*, 22–31. http://dx.doi.org/10.1037/1076-898X.13.1.22.

Foti, D., Weinberg, A., Dien, J., & Hajcak, G. (2011). Event-related potential activity in the basal ganglia differentiates rewards from nonrewards: Temporal spatial principal components analysis and source localization of the feedback negativity. *Human Brain Mapping, 32*, 2207–2216. http://dx.doi.org/10.1002/hbm.21182.

Gehring, W. J., & Willoughby, A. R. (2002). The medial frontal cortex and the rapid processing of monetary gains and losses. *Science, 295*, 2279–2282. http://dx.doi.org/10.1126/science.1066893.

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*, 905–912. http://dx.doi.org/10.1111/j.1469-8986.2007.00567.x.

Holroyd, C. B., & Coles, M. G. H. (2002). The neural basis of human error processing: Reinforcement leaning, dopamine, and the error-related negativity. *Psychological Review, 109*, 679–709. http://dx.doi.org/10.1037//0033-295X.109.4.679.

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*, 688–697. http://dx.doi.org/10.1111/j.1469-8986.2008.00668.x.

Kastenmüller, A., Fischer, P., & Fischer, J. (2014). Video racing games increase actual health-related risk-taking behavior. *Psychology of Popular Media Culture, 3*, 190–194. http://dx.doi.org/10.1037/a0030559.

Kirsh, S. J., & Mounts, J. R. W. (2007). Violent video game play impacts facial emotion recognition. *Aggressive Behavior, 33*, 353–358. http://dx.doi.org/10.1002/ab.20191.

Liu, X., Hairston, J., Schrier, M., & Fan, J. (2011). Common and distinct networks underlying reward valence and processing stages: A meta-analysis of functional neuroimaging studies. *Neuroscience & Biobehavioral Reviews, 35*, 1219–1236. http://dx.doi.org/10.1016/j.neubiorev.2010.12.012.

Lobaugh, N. J., West, R., & McIntosh, A. R. (2001). Spatiotemporal analysis of experimental differences in event-related potential data with partial least squares. *Psychophysiology, 38*, 517–530. http://dx.doi.org/10.1017/S0048577201991681.

McIntosh, A. R., & Lobaugh, N. J. (2004). Partial least squares analysis of neuroimaging data: Applications and advances. *Neuroimage, 23*, S250–S263. http://dx.doi.org/10.1016/j.neuroimage.2004.07.020.

National Highway Traffic Safety Administration. (2009). Retrieved June 20, 2011, from http://www.nhtsa.gov/FARS.

Nieuwenhuis, S. (2011). Learning, the P3, and the locus coeruleus-norepinephrine system. In R. B. Mars, J. Sallet, M. F. S. Rushworth, & N. Yeung (Eds.), *Neural basis of motivational and cognitive control* (pp. 209–222). Cambridge, MA: The MIT Press.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*, 97–113. http://dx.doi.org/10.1016/0028-3932(71)90067-4.

Potts, G. F., Martin, L. E., Burton, P., & Montague, P. R. (2006). When things are better or worse than expected: The medial frontal cortex and the allocation of processing resources. *Journal of Cognitive Neuroscience, 18*, 1112–1119. http://dx.doi.org/10.1162/jocn.2006.18.7.1112.

Powers, K. L., Brooks, P. J., Aldrich, N. J., Palladino, M. A., & Alfieri, L. (2013). Effect of video-game play on information processing: A meta-analytic investigation. *Psychonomic Bulletin & Review, 20*, 1055–1079. http://dx.doi.org/10.3758/s13423-013-0418-z.

Walsh, M. W., & Anderson, J. R. (2012). Learning from experience: Event-related potential correlates of reward processing, neural adaptation, and behavioral choice. *Neuroscience & Biobehavioral Reviews, 36*, 1870–1884. http://dx.doi.org/10.1016/j.neubiorev.2012.05.008.

West, R., Bailey, K., Anderson, S., & Kieffaber, P. D. (2014a). Beyond the FN: A spatio-temporal analysis of the neural correlates of feedback processing in a virtual blackjack game. *Brain & Cognition, 86*, 104–115. http://dx.doi.org/10.1016/j.bandc.2014.02.003.

West, R., Bailey, K., Tiernan, B. N., Boonsuk, W., & Gilbert, S. (2012). The temporal dynamics of medial and lateral frontal neural activity related to proactive cognitive control. *Neuropsychologia, 50*, 3450–3460. http://dx.doi.org/10.1016/j.neuropsychologia.2012.10.011.

West, R., Tiernan, B. N., Kieffaber, P. D., Bailey, K., & Anderson, S. (2014b). The effect of age on the neural correlates of feedback processing in a naturalistic gambling game. *Psychophysiology, 51*, 734–745. http://dx.doi.org/10.1111/psyp.12225.

West, R., & Travers, S. (2008). Tracking the temporal dynamics of updating cognitive control: An examination of error processing. *Cerebral Cortex, 18*, 1112–1124. http://dx.doi.org/10.1093/cercor/bhm142.

Yeung, N., & Sanfey, A. G. (2004). Independent coding of reward magnitude and valence in the human brain. *Journal of Neuroscience, 24*, 6258–6264. http://dx.doi.org/10.1523/JNEUROSCI.4537-03.2004.