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Revenge is Sweet: Investigation of the Effects of Approach-Motivated Anger on the RewP in the Motivated Anger Delay (MAD) Paradigm

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Abstract

Past research has found that neural activity associated with feedback processing is enhanced by positive approach-motivated states. However, no past work has examined how reward processing changes in the context of revenge. Using a novel aggression paradigm, we sought to explore the influence of approach-motivated anger on neural responses to feedback indicating the opportunity to seek revenge against an offending opponent by examining the reward positivity (RewP), an event-related potential indexing performance feedback. In Experiment 1, after receiving insulting feedback from an opponent, participants played a reaction time game with three trial types: revenge trials, aggravation trials, and no-consequence trials. Results revealed that RewP amplitudes were larger to revenge trial win feedback than no-consequence trial win feedback or revenge trial loss feedback. RewP amplitudes were larger to both aggravation trial win and loss feedback than on no-consequence trials. Experiment 2 examined the influence of approach-motivated anger during the acquisition of rewards on the RewP without the possibility of retribution from the offending individual. Participants played a reaction time game similar to Experiment 1, except instead of giving or receiving noise blasts, participants could win money from the insulter (revenge trials) or a neutral-party (e.g., bank). Results indicated that revenge wins elicited larger RewP amplitudes than bank wins. These results suggest that anger enhances revenge-related RewP amplitudes to obtaining revenge opportunities and further aggravation wins or losses. Anger appears to enhance the pleasurable feelings of revenge.

KEYWORDS
anger, approach motivation, goal pursuit, revenge, reward positivity

1 | INTRODUCTION

> "It [revenge] is far sweeter than honey."
> — Homer, *The Illiad*

Individuals pursue revenge as perceived rewarding events, in which there exists a belief that the act of revenge will be satisfying or pleasurable (Carlsmith & Darley, 2008). The perception of the utility of revenge appears to be widespread; indeed, even a brief review of a wide array of

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media, including literature, popular entertainment, and religious and legal writings, suggest that revenge is a natural response to perceived offenses. Additionally, revenge appears to be highly motivating, even to the extent of motivating and justifying extreme amoral behavior. For example, an estimated 20% to 40% of homicides in the United States appear to be motivated by revenge (U.S. Department of Justice, 2017; Kubrin & Weitzer, 2003), suggesting that revenge is a widespread social phenomenon that impacts the lives of millions of people. While individuals often come to regret their revengeful actions, within the present moment, the act of revenge appears to "feel good" by eliciting positive emotions as one presumably rectifies an angering situation (Chester, 2017; Knutson, 2004; Trivers, 1971). Thus, while revenge-seeking behaviors are often the product of anger toward a situation, revenge-seeking behaviors are manifested out of a desire to experience a rewarding feeling of gratification, which often occur when simply knowing that one has the ability to seek revenge against an offender. However, the neural mechanisms associated with the pleasurable aspects of revenge-seeking has received relatively little research. The present research was designed to understand the neural underpinnings of emotional reactions to winning the opportunity to partake in revenge, as well as further offense.

1.1 | Characteristics of revenge

Revenge refers to a desirable aggressive reaction in response to a harmful action (Schumann & Ross, 2010). More specifically, revenge is a motivated act driven by the goal to see a transgressor suffer (Zaibert, 2006). This explicitly differs from retributive punishment, in that the goal of revenge is not to merely retaliate against the offending party to show that some behavior is bad, but to alleviate intense negative emotions via making an offender suffer (Grobbink, Derksen, & van Marle, 2015). Thus, while punishment is considered a form of justice, revenge stems from feelings of anger or vengeance toward an individual or situation (Feinberg, 1970).

Individuals seeking justice often believe that revenge will be a positive experience with the goal of bringing about catharsis toward an angering event (Bushman, 2002; Chester & DeWall, 2017; Chester, Merwin, & DeWall, 2015). This makes sense, given that past research has found that attaining goals results in greater cheerfulness responses (Higgins, Shah, & Friedman, 1997). In the context of revenge, the individual seeking revenge anticipates feeling better and having a better mood after an aggressive response toward some offender (Baumeister, Vohs, DeWall, & Zhang, 2007; Bushman, 2002). Increases in positive affect after an aggressive reaction occur because the individual seeking revenge believes that justice has been distributed to an offender (Frijda, 1994). Individuals appear to partake in these behaviors with the desire to increase positive affect after an angering situation.

1.2 | Anger: An emotional driver of revenge

Aggression often occurs in response to some frustration (Berkowitz, 1989). However, aggressive revenge, more specifically, is thought to be driven by negative affects such as anger in response to some transgression (Harmon-Jones & Sigelman, 2001). Anger is experienced as an unpleasant emotional state often associated with the approach motivational system (Harmon-Jones, 2004; Harmon-Jones, Schmeichel, Mennitt, & Harmon-Jones, 2011; Threadgill & Gable, 2019a). Approach motivation, or the impetus to move toward some goal or object, is a fundamental dimension of affective states (Gable, Neal, & Threadgill, 2018; Gable, Threadgill, & Adams, 2016; Harmon-Jones, Harmon-Jones, & Price, 2013; Pizzagalli, Sherwood, Henriques, & Davidson, 2005; Ridderinkhof, 2017; Threadgill & Gable, 2018a, 2019b). Much research has associated anger with approach motivation (for review, see Carver & Harmon-Jones, 2009). For example, anger is associated with approach-motivated urges (Dollard, Miller, Doob, Mowrer, & Sears, 1939; Harmon-Jones, Price, Peterson, Gable, & Harmon-Jones, 2013), approach-oriented patterns of physiological responses (Jameison, Koslov, Nock, & Mendes, 2012) and relates to more approach-motivated traits such as self-assurance, strength, and bravery (Izard, 1991; Lerner & Keltner, 2001). Moreover, neural regions associated with approach motivation are activated during situational anger (see Gable & Poole, 2014; Gable, Poole, & Harmon-Jones, 2015; Harmon-Jones & Gable, 2018, for a review).

Past work has suggested that retaliatory aggression can be approach-motivated. Harmon-Jones and Sigelman (2001) found that, after an insult, participants who had greater left frontal alpha asymmetry, a neural correlate of approach motivation, engaged in more aggressive behavior. In contrast, participants who were led to believe that they could not act on their anger by taking actions to resolve an anger-inducing event showed less left frontal alpha asymmetry than those who did expect to be able to resolve an anger-inducing event (Harmon-Jones, Sigelman, Bohlig, & Harmon-Jones, 2003), suggesting that the ability to rectify an angering-situation is approach-motivating.

Other work has shown that participants rate aggressive responses after being provoked as more pleasurable than unjustified aggression (Ramirez, Bonniot-Cabanac, & Cabanac, 2005). Chester et al. (2016) found that greater sensation-seeking mediated the relationship between dopamine receptor gene polymorphisms (which is associated with reward seeking behaviors) and previous history of aggression. Additionally, retaliatory behaviors are associated with activity in the ventral striatum, a key component of the reward system in the brain (Chester & DeWall, 2018). Together, this work suggests that approach-motivated anger is related to both aggressive behaviors and the experience of positive emotions, such as pleasure after aggression.

Based on this past work, an important next step in understanding revenge is to examine how anger impacts the experience of winning the opportunity for revenge. It seems likely that simply winning the opportunity for revenge may elicit emotional responses similar to the pleasant feelings elicited by partaking in revengeful behaviors. No past work has examined how anger impacts the rapid neural reactions to winning the opportunity to partake in revenge-seeking behaviors. Therefore, we conducted two studies in which participants were made angry by an ostensible aggressor. Participants then engaged in a novel aggression paradigm where, on some trials, they were able to seek revenge against the offending individual, while, on other trials, participants simply beat their opponent in a reaction time game. The present studies sought to shed light on transitory reactions to winning the opportunity to seek revenge against a transgressor. To examine these momentary reactions to winning the ability to get revenge toward an angering situation, we examined the reward positivity (RewP), an ERP component that evaluates outcomes as either positive or negative.

1.3 | The reward positivity as a neural correlate of revenge and goal success

Integral to the examination of goal pursuit is understanding feedback signaling the success or failures of goal pursuit actions. This action monitoring enhances processing of rewarding feedback in order to maximize the probability of attaining rewards (Krigolson, Hassall, & Handy, 2014; Sutton & Barto, 1998). The RewP is an ERP component generated along the fronto-central midline and is sensitive to action outcomes (Proudfit, 2015). Traditionally known as the feedback (−related) negativity, this ERP component is an underlying positive-going deflection occurring in the time range of approximately 250 ms at frontocentral sites. Positive (i.e., win) feedback tends to evoke a larger positive-going wave than negative (i.e., loss) or neutral feedback (Holroyd, Krigolson, & Lee, 2011; Threadgill et al., 2020; Weinberg, Riesel, & Proudfit, 2014), likely reflecting midbrain phasic dopaminergic firing in the cingulate cortex (Carlson, Foti, Mujica-Parodi, Harmon-Jones, & Hajcak, 2011; Holroyd & Yeung, 2012; Krigolson, 2018; Schultz, 2007). This suggests that the RewP reflects a binary evaluation of feedback as either rewarding or nonrewarding (Hajcak, Moser, Holroyd, & Simons, 2006), as well as coding prediction errors involved in reinforcement learning (Holroyd & Coles, 2002; Ullsperger, Danielmeier, & Jocham, 2014).

Recent research has found that changes in RewP amplitude may go beyond simple good vs. bad associations to also incorporate the motivational salience of feedback (Bromberg-Martin, Matsumoto, & Hikosaka, 2010; Esber & Haselgrove, 2011; Gehring & Willoughby, 2002; Hird, El-Deredy, Jones, & Talmi, 2018; Oliveira, McDonald, & Goodman, 2007). For example, past work has found that enhancing positive approach motivation enhances feedback processing of successful outcomes (Threadgill & Gable, 2016, 2018b; Wilhelm, Miller, & Gable, 2019). Other work has found that enhancing the motivation of both positive and negative outcomes modulates a larger RewP (Talmi, Atkinson, & El-Deredy, 2013). Furthermore, clinical disorders associated with decreased approach motivation (such as depression) decrease the RewP (Brush, Ehmann, Hajcak, Selby, & Alderman, 2018; Proudfit, 2015).

All past work suggests that the RewP may be sensitive to either the motivational salience or the valence of outcomes. However, past experiments are limited in that they have only examined valence (positive vs. negative or neutral) outcomes on the RewP, or they have only examined the influence of positive affects high in approach on the RewP. Thus, all obtained results suggesting that approach motivation causes enhanced feedback processing could be interpreted as being due to approach-positive states. The present research was designed to clarify these conceptual issues by examining the effect of anger, a negatively-valenced approach-motivated state, on reward processing via being able to seek revenge against an offending subject.

While past work has suggested that only positive states in the form of winning feedback could elicit the RewP, it may be the case that negative approach-motivated states would elicit a larger RewP when winning the ability to pursue revenge opportunities, and prevent further aggression, due to increases in motivational salience, relative to a neutral state. If winning the ability to seek revenge toward an angering situation elicits a distinct RewP, then motivation to pursue revenge occurs in order to evoke feelings of satisfaction or euphoria. However, if winning the opportunity to seek revenge against an angering situation does not elicit a distinct RewP, then it is likely the case that the RewP simply tracks the valence of outcomes, as opposed to the motivational salience of the outcome.

1.4 | The current experiments

Examining neural activity while winning the opportunity to seek revenge against an offending opponent in angry individuals provides a unique paradigm to examine how approach motivation undergirds revenge-seeking behavior. The current studies utilized a novel social-aggression paradigm to evoke approach-motivated anger and assess revenge-seeking behavior toward (or further provocation from) an ostensible participant who insulted them. Experiment 1 examined wins and losses when winning (vs. losing) the opportunity to get revenge against (revenge trials) or wining (vs. losing) the possibility of further aggression by an offending opponent (aggravation trials). Because it was possible that Experiment 1 may have elicited both approach and avoidance motivation during the social-aggression paradigm, Experiment 2 sought to explore the unique role of approach-motivated anger by eliminating conditions that could possibly evoke avoidance-motivated states (e.g., further aggression). More specifically, we removed the ability for the offending individual to further provoke participants and, instead, gave participants the ability to win a monetary award from a neutral third-party.

In Experiment 1, it was hypothesized that approach-motivated anger would increase reward processing to winning the opportunity to seek revenge or taking the opportunity to aggress away from an insulter in participants who demonstrate anger toward an insult. Specifically, we predict that the RewP would be larger to win feedback following revenge trials and aggravation trials than win feedback following no-consequence trials. Furthermore, depending on whether the RewP is most influenced by valence or approach motivation, RewP amplitudes to loss feedback could exhibit two divergent patterns of activity. If valence alone is driving the RewP, then RewP amplitudes to losses should be similar between conditions. However, if approach motivation independently influences RewP amplitudes, then enhanced approach motivation to losses on aggravation trials should enhance the RewP to loss feedback, relative to no-consequence trial losses.

Finally, given the novel nature of our experimental paradigm (the Motivated Anger Delay Paradigm, or the MAD Paradigm), across both studies, we included three manipulation check measures. We predict that the anger manipulation would increase self-reported anger, relative to a baseline measurement of anger occurring before the anger manipulation. We also predicted that motivated trials would increase excitement and anger as compared to neutral trials. Lastly, we predicted that motivated trials would show faster responses to the goal-directed task, as compared to neutral trials.

2 | EXPERIMENT 1

All experimental protocols, example documents, stimuli, computer scripts, and data for both experiments are available online at https://osf.io/7v94a/ (doi: 10.17605/OSF.IO/7V94A).[1] The research protocol for both studies was approved by the Institutional Review Board at the University of Alabama.

2.1 | Methods

2.1.1 | Participants

A priori power analyses were conducted using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). In the calculation of our required sample size for Experiment 1, we sought to use conservative estimates of parameters in our calculation to make sure that we were adequately powered. More specifically, we used a medium partial-eta squared effect size of .07, which is less than half the effect size found by Threadgill and Gable (2016); this was also smaller than the effect sizes found in Threadgill & Gable, 2018b) when examining the influence of approach motivation on the RewP. Furthermore, we calculated power at 95%, as opposed to the customary 80% that is typically recommended. Finally, we also used the correlation amongst repeated-measures of .6, as that was the correlation between wins and losses that we have found in our lab in previous research (Threadgill & Gable, 2016, unpublished analysis). Based upon the stated parameters, we determined that a sample size of 40 participants was sufficient.

Additionally, we conducted pilot testing without collecting physiological data both to have research assistants extensively practice the protocol that we planned to use while collecting physiological data and to gain an approximate understanding of how many participants would fail to believe the manipulation. Pilot testing including 59 participants suggested that approximately one-third of participants indicated during a suspicion probe at the end of the experimental session that they either did not believe that the insult came from another individual or did not experience anger toward the insulting aggressor (see Procedures for our exclusionary criterion used when collecting EEG data). Therefore, we collected data from 60 right-handed individuals, who participated in exchange for partial course credit.

2.1.2 | Paradigm

To test our hypotheses, we developed the motivated anger delay (MAD) paradigm, based in part on the essay feedback provocation paradigm (Bushman & Baumeister, 1998), the Taylor aggression paradigm (Taylor, 1966), and the monetary incentive delay paradigm (Knutson, Westdorp, Kaiser, & Hommer, 2000; see Figure 1 for experiment flowchart of MAD paradigm). In our task, participants were first insulted by receiving negative feedback on an essay they wrote,

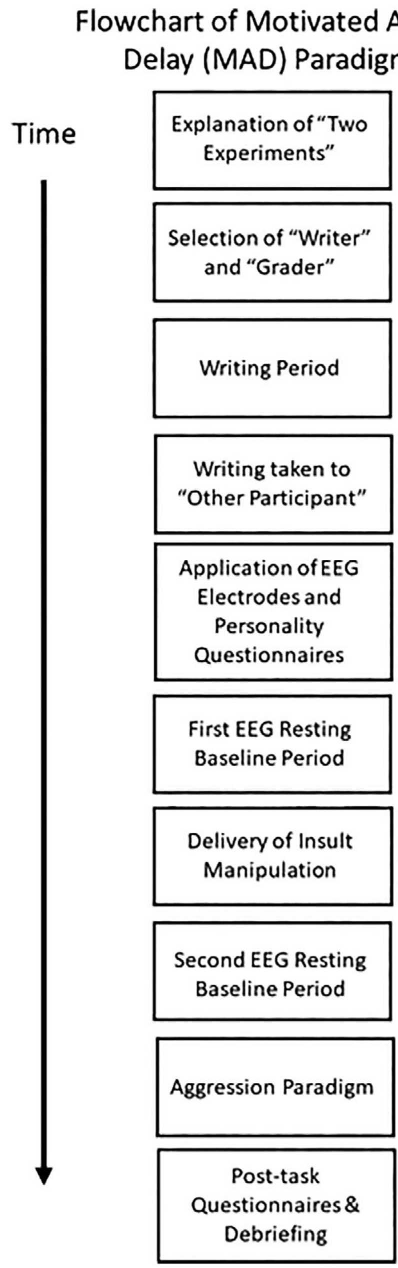

FIGURE 1 Flowchart of MAD paradigm

ostensibly from another participant (the "insulter"). This insult was designed to make participants angry toward the other individual. Participants were then able to act on their anger through a competitive reaction time task (e.g., flanker task; Eriksen & Eriksen, 1974). In the task, participants can win the opportunity to either deliver low noise blasts against their opponent (revenge trials) or prevent their opponent from blasting them with noise (aggravation trials). It is likely the case that when an individual is angry at their opponent, wins that reward the participant and punish the offending opponent increase approach-motivated excitement. In contrast, losses that reward the offending opponent and punish the participant increase approach-motivated aggravation in participants. A third, no-noise blast condition served as a competitive no-consequence (i.e., no noise blast was exchanged) comparison.

2.1.3 | Procedures

Participants were brought into the lab alone. Participants were told by a trained research assistant that they would be taking part in two experiments: the first one was to examine the relationship between personality variables and writing styles, and the second one involved playing a reaction time game against another participant. Experimenters told participants that there was a second participant in the adjacent room with whom they would be interacting. This person did not actually exist. Effort was made to increase the believability of the ostensible opponent. These details are provided in the Supplementary Materials.

2.1.4 | Insult manipulation

After giving consent, participants were told that the first study involved one participant writing an essay, while the other participant evaluated the essay (see Supplementary Materials; Bushman, Baumeister, & Phillips, 2001; Harmon-Jones & Sigelman, 2001; Harmon-Jones, Vaughn-Scott, Mohr, Sigelman, & Harmon-Jones, 2004). Participants were then given the "Social Attitudes Assessment." On it, they were instructed to write an essay defending their position on a controversial issue, picking a subject that is the most important to that individual from a list of controversial topics. Examples include reducing the drinking age, the legality of same-sex marriage, and the legality of abortion. After 10 min, the experimenter stopped the participant, who then pretended to take the essay to the other participant to be graded.

After "delivering" the essay, the participant completed a variety of personality surveys that the "grader" had ostensibly completed during the writing phase. Participants also filled out the PANAS-X (Watson & Clark, 1999) to measure their emotional state before receiving feedback. Once the participant has finished filling out the personality questionnaires, the experimenter applied EEG sensors and recorded 4 min of resting EEG activity, which has been used in past research using a similar manipulation (Peterson, Shackman, & Harmon-Jones, 2008). Participants were given instructions over a speaker to sit quietly with their eyes open or closed (alternating for 1 min at a time). While resting data was recorded with the participant's eyes open (2 min), participants were instructed to look at the center of a blank computer monitor in front of them.

The experimenter then returned to the experiment room, presumably to set up for the next experiment. In reality, the experimenter was delivering the insulting feedback to participants (see Supplementary Materials). The feedback was designed to be insulting based off previous studies using feedback to evoke anger (Harmon-Jones & Peterson, 2009; Hortensius, Schutter, & Harmon-Jones, 2012; Peterson et al., 2008). The feedback consisted of ratings on several different categories, allegedly given by the other participant. Participants saw ratings on a 1–9 bipolar scale on six characteristics. The anchors shown were unintelligent (1)—intelligent (9), thought-provoking (1)—boring (9), friendly (1)—unfriendly (9), illogical (1)—logical (9), respectable (1)—unrespectable (9), and irrational (1)—rational (9). Participants were given a rating of 2 or 3 when negative words were represented by a 1, and 7 or 8 when negative words were represented by a 9. At the bottom of the page, the feedback had a hand-written note saying, "I can't believe an educated person would think like this. I hope this person learns something while at [the University of Alabama]! I can't even believe that they would think that [issue] should be [allowed/not allowed]!" Pilot testing of this manipulation revealed that this feedback increased anger, frustration, and hostility, relative to baseline levels at the beginning of the experiment.

Once the participant has finished reading the feedback, the experimenter told the participant that they needed to take a second baseline recording, ostensibly because they were waiting on the other participant to finish their baseline recordings. Participants were instructed to think about how they presently felt while EEG data was recorded for 1 min with eyes open, which has been used in past research using a similar manipulation (Harmon-Jones & Sigelman, 2001).[2] Participants were instructed over a speaker to look at the center of a blank computer monitor in front of them while resting activity was recorded.

2.1.5 | Aggression task

After the second baseline recording, the experimenter returned to the experiment room and explained the second study. Participants were told that they would be competing against the other participant in a reaction time game. They were told that the computers were connected in real time through cables in the back of the room, and all feedback was dependent on which participant was quicker to respond correctly. The experimenter told the participant that the game would begin once they had given the other participant the instructions. The experimenter left the room, waited for 30 *s*, and started the game. Instructions for the game were presented on the computer.

The game was modeled after previous aggression tasks (Bartholow & Anderson, 2002; Peterson et al., 2008; Taylor, 1966), in which participants were given the opportunity to blast the insulter

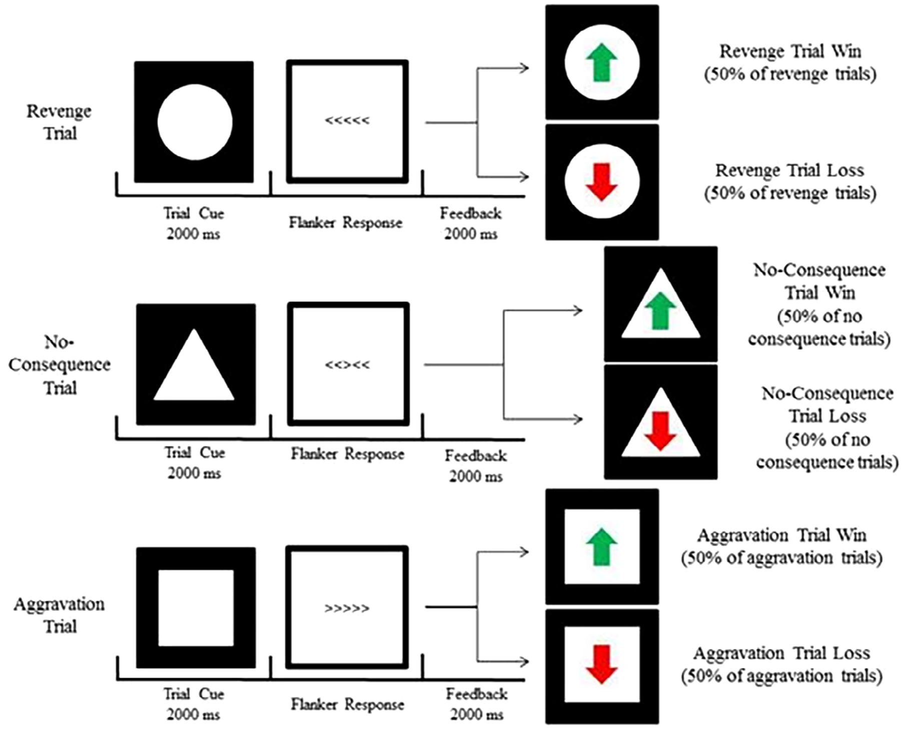

FIGURE 2 Experiment 1 example trials. Between the trial cue and flanker response, there was an ISI of 500 ms. Between the flanker response and feedback, there was an ISI of 500 ms. The intertrial intervals were 4,000 ms. A black screen was presented during all ISI's and ITI's

with noise if they were faster than their opponent in a reaction time game. Each trial (*n* = 72; see Figure 2) began with a trial cue displayed in the center of a computer monitor, consisting of one of the following shapes: a white circle, a white triangle, or a white square. Circles represented revenge trial cues. Squares represented aggravation trial cues. Triangles represented no-consequence trial cues. One-third of the trials were revenge trials (*n* = 24), one-third of the trials were no-consequence trials (*n* = 24), and one-third of the trials were aggravation trials (*n* = 24). No trial type was presented more than three consecutive times.

After the trial cue, participants completed the goal-related task, which was a flanker response (Eriksen & Eriksen, 1974). Participants indicated the direction of a center arrow by pressing the left or right shift key as quickly as possible. The flanker response remained on the screen until the participant responded. Participants were told that faster responses than their opponent would win the trial. On revenge trials, if the participant won, they had the opportunity to blast the insulter with a loud (102 dB) noise. If they lost, then nothing happened. On no-consequence trials, there was no-consequence (e.g., no noise blast was exchanged), regardless of whether the participant won or lost. Participants were told that results of the no-consequence trials were random and unrelated to reaction time to the flanker response. On aggravation trials, if the participant lost, the insulter could blast the participant with noise. If the participant won, then nothing happened. It was predicted that losing on this trial to the insulter would cause greater aggravation.

The noise blast was equivalent to the average car or house stereo at maximum volume at close range (Gable & Harmon-Jones, 2009). Prior to the participant arriving, the experimenter checked the noise level volume in the headphones using the Decibel 10th application on an Apple iPhone (fourth generation) to ensure that 102 dB was reached by the headphones.

Following the flanker response, participants received feedback indicating whether they did or did not win on that trial. A white circle, triangle, or square (corresponding with the trial type) was presented with an arrow pointing either a green up arrow or red down arrow, indicating win or loss feedback, respectively.

Trial outcome was fixed for all trials. Half of the revenge trials, half of the no-consequence trials, and half of the aggravation trials resulted in a win (*n* = 12 for revenge trials, *n* = 12 for no-consequence trials, and *n* = 12 for aggravation trials). The remaining trials resulted in a loss. On revenge trials and aggravation trials, participants received loss feedback if they gave an incorrect response or if their response exceed 1,500 ms. Incorrect flanker responses were removed from analysis of flanker reaction times (revenge trials: 82.20% retained; no-consequence trials: 88.03% retained; aggravation trials: 88.03% retained).

If a revenge trial resulted in win feedback, participants were able deliver up to 10 s of a 102 dB white noise to the insulter. Upon receiving win feedback, participants were required to indicate how long they wished for the noise blast to be (1 = *5 seconds*, 6 = 10 *seconds*; participants were not allowed to "opt out" of blasting their opponent). After selection of how long the noise blast would be, the "noise blast" was delivered for the length of time indicated by the participant. If a revenge trial resulted in loss feedback, the game simply proceeded to the next trial. Regardless of whether a no-consequence trial resulted in win feedback or loss feedback, the game simply proceeded to the next trial, because neither participant was able to blast the other participant with a loud noise.

If an aggravation trial resulted in win feedback, the game simply continued to the next trial. However, if an aggravation trial resulted in loss feedback, participants waited between 5 and 7 *s* as the insulter made a noise selection. A noise blast was then delivered through stereo headphones. The noise blast that was delivered at 102 dB and lasted for either 5 or 7 *s*.

Six practice trials occurred at the beginning of the experiment (two of each trial type with each trial type resulting with one win and one loss) and were not included for analyses. In between each trial, participants were prompted to click the spacebar to proceed to the next trial, followed by a screen indicating that the computer is waiting on the opponent (300–700 ms waiting period). The game lasted for approximately 50 min. During debriefing, all participants reported that they were engaged throughout the entirety of the game, and no participants reported being fatigued.

After the game, participants completed the PANAS-X (Watson & Clark, 1999) a second time. Furthermore, participants rated how they felt during each of the three trial cues and each of the six possible feedback cues presented in the MAD paradigm on a scale of 1 (*no emotion*) to 9 (*strongest feeling*; Ekman, Friesen, & Ancoli, 1980). The feelings assessed were as follows: sad, glad, nervous, enthusiastic, happy, excited, angry, down, mad, and anxious. Because we were only interested in high intensity approach-motivated states, we only examined those ratings. To examine how participants generally felt toward trial cues and trial feedback pictures, words assessing similar affective responses were averaged across picture type to form indices for excitement (excited and enthusiastic; Cronbach's alpha = .73) and anger (angry and mad; Cronbach's alpha = .88). Ratings data with no responses were removed from analyses, leading to variations in degrees of freedom for analyses. Finally, participants were carefully probed for suspicion using standardized funnel questioning and debriefed.

2.1.6 | EEG processing

Electroencephalography was recorded from 32 tin electrodes mounted in a stretch lycra Quick-Cap (Electroc-Cap, Eaton, OH) based on the 10–20 system and referenced online to the left earlobe. A ground electrode was mounted midway between FPz and Fz. A sodium-chloride based conductance gel was used to reduce impedance under 5,000 Ω. Signals were amplified with a Neuroscan SynAmps RT amplifier unit (El Paso, TX), low-pass filtered at 100 Hz, high-pass filtered at 0.05 Hz, notch-filtered at 60 Hz, and digitized at 500 Hz. Artifacts (e.g., horizontal eye movement and muscle) were removed by hand. Then, a regression-based eye movement correction was applied (Semlitsch, Anderer, Schuster, & Presslich, 1986), after which the data was visually inspected again to ensure proper correction.

2.1.7 | Frontal asymmetry assessment

Epochs 1.024 *s* in duration during the baseline periods were extracted through a Hamming window (50% taper of distal ends). Data were re-referenced using an average ears reference composed of the average activity at the earlobes. Consecutive epochs were overlapped by 50% to minimize data loss due to windowing. Power values within the alpha band (8–13 Hz) were obtained using a fast Fourier transformation and averaged across epochs (Coan & Allen, 2004; Harmon-Jones & Sigelman, 2001). Because different studies measuring approach-motivated anger have used various alpha asymmetry difference scores (Harmon-Jones & Sigelman, 2001; Keune et al., 2012; Peterson et al., 2008; Peterson, Gravens, & Harmon-Jones, 2011; Poole & Gable, 2014; Threadgill, Ryan, Jordan, & Hajcak, 2020), we used the asymmetry score showing the maximal difference between left and right frontal alpha activity from four asymmetry difference scores (F3/4, F5/6, F7/8, and an index of all three pairs of frontal sites) by subtracting the natural log left from the natural log right alpha activity. The difference between left and right frontal alpha activity was maximal at lateral-frontal sites F7 and F8 (Cronbach's alpha for the first baseline period = .989; Cronbach's alpha for the second baseline period = .908).[3] Because alpha activity is inversely related to cortical activation (Laufs et al., 2003; Lindsley & Wicke, 1974), higher scores indicated greater relative left frontal activity.

2.1.8 | ERP assessment

EEG data were epoched from 200 ms before feedback onset until 1,200 ms after feedback onset, re-referenced to the average ears reference, and low-pass filtered at 35 Hz. Aggregated waveforms for each feedback type were created and baseline corrected using the prestimulus activity. Twelve trials were entered into each of the average waveforms for revenge trial wins, revenge trial losses, no-consequence trial wins, no-consequence trial losses, aggravation trial wins, and aggravation trial losses. Based on past research, the RewP mean amplitude was assessed at site Cz within a window of 250–350 ms after feedback onset, because this electrode site and time window had the greatest difference between wins and losses (Baker & Holroyd, 2011; Foti, Weinberg, Dien, & Hajcak, 2011; Threadgill & Gable, 2016).[4]

2.1.9 | Experimental design and statistical analysis

Some have suggested that participants who fail to show psychophysiological markers of the target emotion, measured independently of the main task, should be excluded from analyses, because it is likely that the manipulation failed to elicit the target emotion (Basso, Schefft, & Hoffman, 1994; Shackman et al., 2006; Stemmler, 2003). Instead of excluding participants on the basis of a retrospective report at the conclusion of the experiment in which participants could possibly be afraid to admit that they either believed the study, experienced anger toward the other participant when receiving negative feedback on the essay, or enjoyed partaking in revenge against the offending opponent (which often can be influenced by researcher degrees-of-freedom, such as interpretations of a participant's ambiguous behavioral cues or choice of words), we excluded participants on the basis of psychophysiological markers collected during the course of the experiment that are indicative of approach-motivated anger, measured independently of the main variable of interest. Using a psychophysiological marker as the criterion for exclusion from analysis allows for more control of individual differences in responses to the anger induction when participants might not be willing or able to accurately report their emotional or motivational state (Rottenberg, Kovacs, & Yaroslavsky, 2017). Furthermore, this allows us to capture emotional states during online assessments without reducing hostile evaluations toward a transgressor (which could occur when completing emotion or believability questionnaires directly proceeding the insult manipulation; Berkowitz, Jaffee, Jo, & Troccoli, 2001). One psychophysiological marker of increased approach-motivated anger that has been used to exclude participants in anger paradigms is increased left frontal alpha asymmetry after an anger induction, relative to a baseline (Harmon-Jones & Sigelman, 2001; Jensen-Campbell, Knack, Waldrip, & Campbell, 2007; Verona, Sadeh, & Curtin, 2009). Increases in left frontal alpha asymmetry have consistently been found to be a reliable biomarker of approach-motivated anger (d'Alfonso, van Honk, Hermans, Postma, & de Haan, 2000; Harmon-Jones & Gable, 2018; Jensen-Campbell et al., 2007; Kelley, Eastwick, Harmon-Jones, & Schmeichel, 2015; Verona et al., 2009). However, a recent meta-analysis found small effect sizes for the relationship between frontal asymmetry and anger (Kuper, Käckenmester, & Wacker, 2019), suggesting that the relationship between frontal asymmetry and anger may not exist across all contexts for all individuals. For example, when anger is not able to be expressed, some individuals do not show a relationship between left frontal alpha asymmetry and anger (Zinner, Brodish, Devine, & Harmon-Jones, 2008). Despite small meta-analytic effects, the insult manipulation should increase frontal asymmetry, supporting past work linking anger and frontal asymmetry.

Because we were primarily interested in the impact of anger on the RewP, we excluded from analyses those participants who failed to show an increase in left frontal alpha asymmetrical activation after the anger induction. More specifically, we created a left frontal alpha asymmetry change score by subtracting the left frontal alpha asymmetry score from the baseline period before the insult manipulation from the left frontal alpha asymmetry score from the baseline period following the insult manipulation. We then excluded all participants who had negative left frontal alpha asymmetry change scores (negative scores indicate that left frontal alpha asymmetry was higher before the insult than after the insult). Data from 14 participants failed to show an increase in left frontal alpha asymmetry. Additionally, two participants' RewP scores were more than three *SD*s from the mean and were subsequently excluded. This left 44 participants for hypothesis testing (see Table 1 for sample characteristics).[5]

All data were analyzed with STATISTICA 7 (version 7.1, StatSoft, 2008) using either dependent-sample *t*-tests or repeated-measures analysis of variance (ANOVA). Variations in degrees-of-freedom are due to a participant missing a score for that particular test. The criterion of statistical significance for all analyses was $p < .05$. All post hoc testing was conducted using Fisher's LSD. Means and *SD*s for all variables are presented in Table 2. Full expanded hypotheses for all manipulation checks can be found in the Supplementary Materials. Correlations between all main variables of interest are presented in Supplementary Tables S1-S3.

TABLE 1 Demographic characteristics of full sample and sample for testing in Experiment 1

Variable	Full sample	Sample for testing
Gender		
Female	54.2	55.8
Male	45.8	44.2
Age	19.24 (1.36)	19.28 (1.35)
Race		
White	84.7	81.4
African-American	11.9	14.0
Other	3.4	4.7
Ethnicity		
Hispanic	3.4	0
Non-Hispanic	96.6	100

Note: Values are percentage or mean (*SD* in parentheses). One participant had missing demographic data for both groups. Full sample demographics $n = 59$; sample for testing demographics $n = 44$.

3 | RESULTS

3.1 | Baseline affect

A dependent-sample *t*-test indicated that participants reported being significantly more angry following the insult ($M = 1.62$, $SD = 1.09$), relative to a baseline state ($M = 1.16$, $SD = 0.54$), $t(40) = 2.57$, $p = .014$, $d = 0.40$.

3.2 | Trial emotion ratings

3.2.1 | Emotion ratings to trial cues

A one-way (trial type: revenge vs. no-consequence vs. aggravation) ANOVA examining excitement ratings to the trial cues was significant (see Table 3). Post hoc analyses revealed that participants were more excited by the revenge trials than the no-consequence trials and aggravation trials, *t*s > 2.65, *p*s < .001, *d*s > 0.44. No-consequence trials elicited more excitement than aggravation trials, $t(36) = 2.24$, $p = .031$, $d = 0.37$. These results suggest participants were most excited by the revenge trials.

A one-way (trial type: revenge vs. no-consequence vs. aggravation) repeated-measures ANOVA examining anger ratings to the trial cues was significant (see Table 3). Post hoc analyses revealed that participants experienced no difference in anger between the revenge trial cues and the no-consequence trial cues, $t(31) = 1.68$, $p = .101$, $d = 0.30$. However, aggravation trial cues elicited significantly more

TABLE 2 Means and *SD* for all variables in Experiment 1

Variable	Revenge trial	No-consequence trial	Aggravation trial
Trial Cue rating			
Excitement	4.31 (2.59)	2.84 (2.22)	1.89 (1.13)
Anger	1.93 (1.53)	1.30 (1.20)	3.49 (2.63)
Win feedback rating			
Excitement	4.82 (2.43)	3.73 (2.54)	6.27 (2.09)
Anger	1.47 (1.01)	1.38 (1.35)	1.38 (1.19)
Loss feedback rating			
Excitement	1.58 (0.83)	1.65 (1.49)	1.61 (1.30)
Anger	3.19 (2.47)	2.56 (2.24)	4.67 (2.95)
Flanker RT (in ms)			
Logged RT	6.35 (0.13)	6.39 (0.14)	6.29 (0.21)
Raw RT	575.93 (76.67)	604.50 (85.15)	551.28 (92.02)
RewP			
Win feedback	19.26 (8.05)	14.38 (10.09)	18.97 (7.02)
Loss feedback	16.00 (6.98)	14.63 (7.41)	18.03 (9.19)

Note: SD are in parentheses.

TABLE 3 Statistical analyses for emotion ratings to trial cues in Experiment 1

Factors (df)	*F*	*p*	η_p^2
Excitement (2, 78)	15.97	< .001	.29
Anger (2, 68)	17.72	< .001	.34

Abbreviation: df, degrees of freedom.

anger than revenge trial cues, $t(31) = 2.99$, $p < .001$, $d = 0.53$. Furthermore, aggravation trial cues elicited significantly more anger than no-consequence trial cues, $t(31) = 4.48$, $p < .001$, $d = 0.79$. These results suggest participants were most angered by the aggravation trials.

3.2.2 | Emotion ratings to feedback cues

Affect ratings to the feedback cues were examined using a 2 (affective state: excitement vs. anger) × 3 (trial type: revenge vs. no-consequence vs. aggravation) × 2 (outcome: win vs. loss) repeated-measures ANOVA. This interaction was significant (see Table 4). This three-way interaction was unpacked by examining the 3 (trial type) × 2 (outcome) interaction for excitement ratings and for anger ratings separately.

For the excitement ratings, there was a significant trial type by outcome interaction (see Table 4). A one-way (trial type: revenge vs. no-consequence vs. aggravation) repeated-measures ANOVA examining excitement ratings to win feedback cues was significant. Post hoc analyses revealed that participants experienced more excitement to revenge trial wins than no-consequence trial wins, $t(32) = 2.84$, $p = .007$, $d = 0.49$. Additionally, aggravation trial wins elicited more excitement than no-consequence trial wins, $t(32) = 6.31$, $p < .001$, $d = 1.08$. Finally, aggravation trial wins elicited more excitement than revenge trial wins, $t(32) = 2.91$, $p = .002$, $d = 0.50$. The one-way (trial type) repeated-measures ANOVA examining excitement ratings to loss feedback cues was not significant.

TABLE 4 Statistical analyses for emotion ratings to feedback cues in Experiment 1

Factors (df)	*F*	*p*	η_p^2
Affective state × trial type × outcome (2, 60)	15.64	<.001	.37
Excitement			
Trial type × outcome (2, 64)	14.44	<.001	.31
Win (2, 64)	17.77	<.001	.36
Loss (2, 64)	0.21	.814	.01
Anger			
Trial type × outcome (2, 68)	10.29	<.001	.23
Win (2, 68)	1.83	.169	.05
Loss (2, 68)	13.04	<.001	.28

Abbreviation: df, degrees of freedom.

For the anger ratings, there was a significant trial type by outcome interaction (see Table 4). A one-way (trial type: revenge vs. no-consequence vs. aggravation) repeated-measures ANOVA examining anger ratings to win feedback cues was not significant. However, the one-way (trial type) repeated-measures ANOVA examining anger ratings to loss feedback cues was significant. Post hoc analyses revealed that participants experienced no differences in anger between revenge trial losses and no-consequence trial losses, $t(33) = 1.41$, $p = .167$, $d = 0.24$. Aggravation trial losses elicited more anger than both revenge trial losses and no-consequence trial losses, *ts* > 3.72, *ps* < .001, *ds* > 0.64.

3.3 | Flanker response reaction times

Reaction times were logarithmically transformed. A one-way (trial type: revenge vs. no-consequence vs. aggravation) repeated-measures ANOVA revealed a significant main effect of flanker response reaction time, $F(2, 78) = 7.14$, $p = .001$, $\eta_p^2 = .15$. Post hoc analyses revealed that reaction times to the flanker response on revenge trials were faster than reaction times on no-consequence trials, $t(39) = 2.21$, $p = .033$, $d = 0.35$. Reaction times to the flanker response on aggravation trials were faster than reaction times on no-consequence trials, $t(39) = 2.95$, $p = .005$, $d = 0.47$. Reaction times to the flanker response on aggravation trials were faster than reaction times on revenge trials, $t(39) = 2.38$, $p = .023$, $d = 0.38$. Both revenge trials and aggravation trials sped reaction times, as compared to no-consequence trials. Aggravation trials sped reaction times more than revenge trials.

3.4 | The reward positivity

To examine differences in RewP amplitude between trial types, we conducted a 3 (trial type: revenge vs. no-consequence vs. aggravation) × 2 (outcome: win vs. loss) repeated-measures ANOVA. Results indicated that there was a significant main effect of trial type. There was also a nonsignificant effect of feedback and a nonsignificant interaction (but both were bordering on significant; see Figures 3-7 and Table 5).[6]

Based on hypotheses, we wanted to investigate how condition influenced win and loss feedback using a series of one-way ANOVAs. For RewP amplitudes to win feedback, a one-way (trial type: revenge vs. no-consequence vs. aggravation) repeated-measures ANOVA was significant. Post hoc analyses revealed that the RewP to revenge trial wins was larger than the RewP to no-consequence trial wins, $t(42) = 3.20$, $p = .003$, $d = 0.49$. Additionally, the RewP to aggravation trial wins was larger than the RewP to no-consequence trial wins, $t(42) = 3.25$, $p = .002$, $d = 0.50$. There was no difference in RewP amplitudes between revenge trial wins and aggravation trial wins, $t(42) = 0.29$, $p = .777$, $d = 0.04$. Together, these results suggest that revenge and aggravation trial wins elicit greater RewP amplitudes than no-consequence trial wins.

For RewP amplitudes to loss feedback, a one-way (trial type: revenge vs. no-consequence vs. aggravation) repeated-measures ANOVA was significant. Post hoc analyses revealed that the RewP to revenge trial losses was similar to the RewP to no-consequence trial losses, $t(44) = 1.23$, $p = .226$, $d = 0.19$. However, aggravation trial losses elicited a larger RewP than no-consequence trial losses ($t(44) = 2.63$, $p = .012$, $d = 0.40$) and a RewP marginally larger than revenge trial losses ($t(44) = 1.90$, $p = .064$, $d = 0.29$). These results suggest that aggravation trial losses elicited a larger RewP than revenge and no-consequence trial losses.

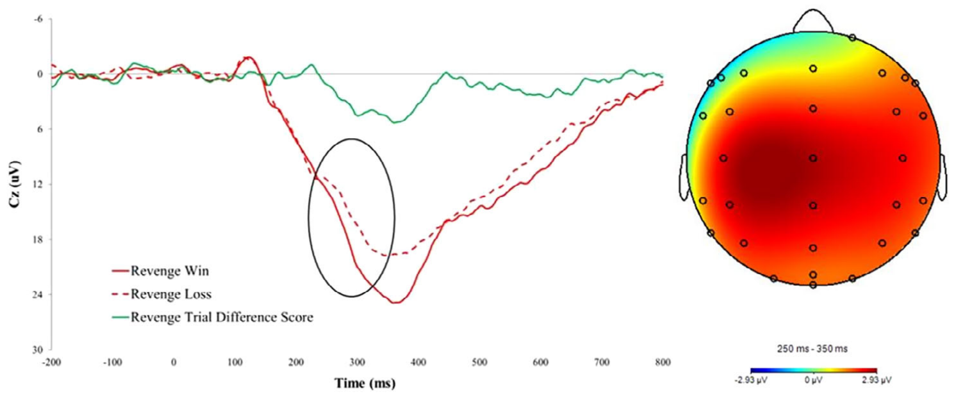

FIGURE 3 Left: ERP waveforms for win and loss feedback during revenge trials in Experiment 1, as well as the difference score between revenge trial wins and revenge trial losses (win minus loss) at site CZ. The RewP component is circled. Note that negative is plotted up by convention. Right: Scalp topography displaying the difference between wins and losses

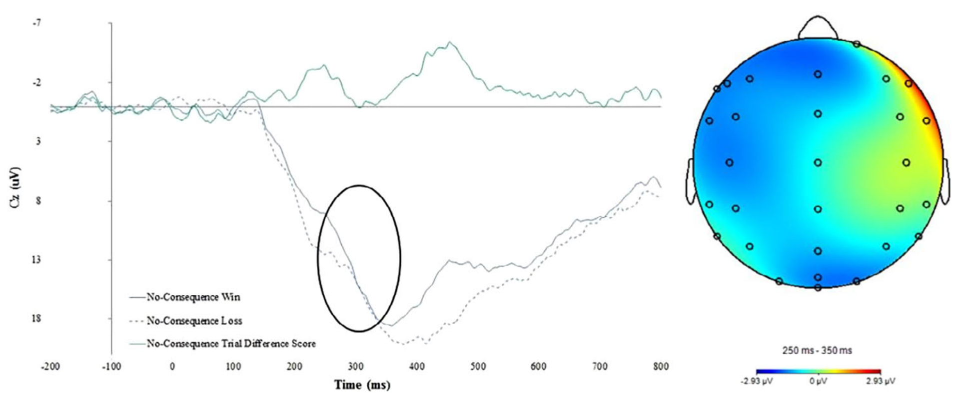

FIGURE 4 Left: ERP waveforms for win and loss feedback during no-consequence trials in Experiment 1, as well as the difference score between no-consequence trial wins and no-consequence trial losses (win minus loss) at site CZ. The RewP component is circled. Right: Scalp topography displaying the difference between wins and losses

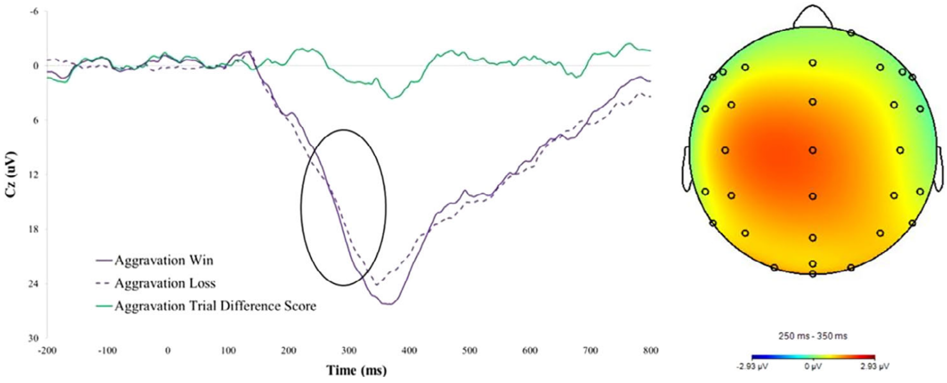

FIGURE 5 Left: ERP waveforms for win and loss feedback during aggravation trials in Experiment 1, as well as the difference score between aggravation trial wins and aggravation trial losses (win minus loss) at site CZ. The RewP component is circled. Right: Scalp topography displaying the difference between wins and losses

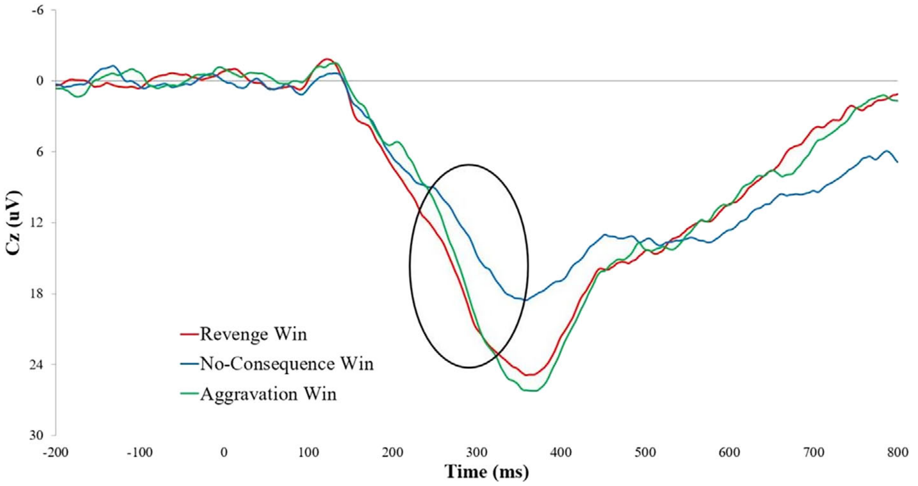

FIGURE 6 ERP waveforms for win feedback during revenge, no-consequence, and aggravation trials in Experiment 1 at site CZ

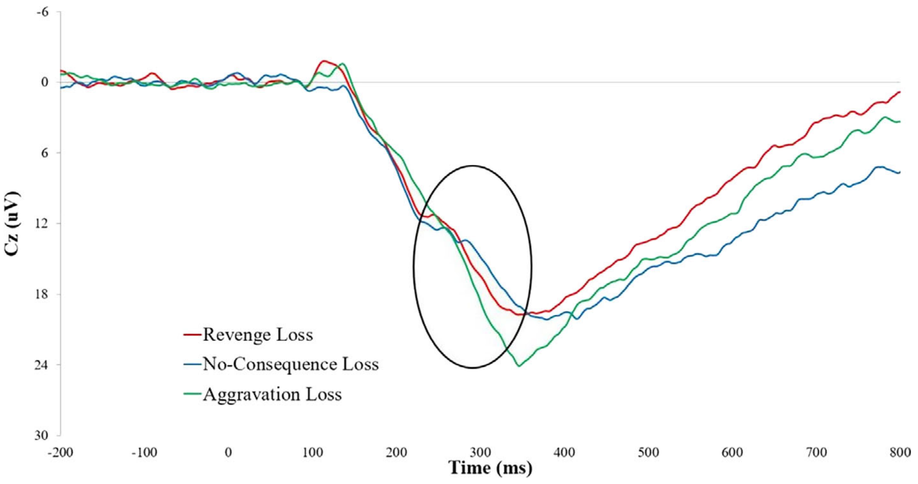

FIGURE 7 ERP waveforms for loss feedback during revenge, no-consequence, and aggravation trials in Experiment 1 at site CZ

TABLE 5 Statistical analyses for the reward positivity in Experiment 1

Factors (df)	*F*	*p*	η_p^2
Trial type (2, 84)	9.77	<.001	.19
Outcome (1, 42)	3.43	.071	.08
Trial type × outcome (2, 84)	2.41	.096	.05
Trial type – Wins (2, 84)	8.41	<.001	.17
Trial type – Losses (2, 84)	4.34	.016	.09

Abbreviation: df, degrees of freedom.

Because the RewP has traditionally been examined by comparing amplitudes during win feedback to amplitudes during loss feedback, we conducted a dependent-sample *t*-test within each trial type. Revenge trial wins elicited a larger RewP than revenge trial losses, $t(43) = 3.10$, $p = .003$, $d = 0.47$. There were no differences in RewP amplitudes between no-consequence trial wins and no-consequence trial losses ($t(43) = 0.22$, $p = .825$, $d = 0.03$) or between aggravation trial wins and aggravation trial losses ($t(43) = 1.14$, $p = .169$, $d = 0.17$).[7]

3.5 | Discussion for experiment 1

Experiment 1 revealed that, when angry, participants experienced more excitement to revenge trial cues than both no-consequence and aggravation trial cues and more anger to aggravation trial cues than both no-consequence and revenge trial cues. This suggests that participants were experiencing approach-motivated affective states during the pursuit of rewards. Additionally, both revenge and aggravation trial win feedback elicited more excitement than no-consequence trial win feedback, while aggravation trial loss feedback elicited more anger than no-consequence and revenge trial loss feedback. This suggests that participants experienced approach-motivated affective states to angering feedback. Behavioral results based on flanker task reaction times support that participants were approach-motivated by the revenge and aggravation conditions. Participants were faster to flanker responses following revenge and aggravation trial cues than no-consequence trial cues. Together with self-reported emotion, these results indicate that participants experienced increased approach-motivated affect in revenge and aggravation trials, relative to no-consequence trials.

RewP amplitudes were larger after revenge trial win feedback than after revenge trial loss feedback in participants who were made angry by an insult manipulation. Consistent with past work, these results suggest that the RewP is more sensitive to win feedback than loss feedback. RewP amplitudes were also larger after both revenge trial win feedback and aggravation trial win feedback than no-consequence trial win feedback. These results suggest that approach-motivated states associated with a goal evoked larger RewPs than neutral states. Finally, aggravation trial loss feedback elicited larger RewP amplitudes than no-consequence trial loss feedback. This suggests that, despite negative feedback, the enhanced approach-motivation associated with further aggravation enhanced RewP amplitudes.

Experiment 1 examined how anger impacts reward processing, with results suggesting that motivational salience, rather than valence, enhances the RewP. However, the results of Experiment 1 could possibly be due to two potential confounds. First, Experiment 1 had participants complete a task with a positive condition (revenge trials), neutral condition (no-consequence trials), and negative condition (aggravation trials). Thus, Experiment 2 removed this confound by replacing the negative aggravation trials with a second positive condition (bank trials) that elicited different levels of approach motivational intensity than revenge trials.

Second, the aggravation condition in Experiment 1 may have also elicited avoidance motivation, because participants were trying to prevent the opponent from being able to blast them with a loud noise. It might be the case that participants feared that the "other participant" may reciprocate excessively aggressive actions with aggressive actions of their own. In order to account for this potential compound, and to fully examine how approach-motivated anger influences the RewP to revenge feedback, we replaced the aggravation condition with a positive approach-motivated condition that did not allow for the possibility of seeking revenge.

4 | EXPERIMENT 2

To address the possibility that aggravation trials may have elicited avoidance-motivation, Experiment 2 replaced this condition with one that could not result in further aggression from the opponent. Thus, Experiment 2 removed this possibility by having participants beat the offending opponent in order to win money without the potential for reciprocal aggression. Participants could win money in one of two ways: participants could either win money from an offending opponent (revenge trials) or from a neutral third-party bank (bank trials). There was no possibility for the offending opponent to take money from the participant.

Furthermore, to examine the unique role of revenge on the RewP, as compared to a general approach-motivated state, Experiment 2 included conditions with the possibility of winning a revenge opportunity and winning an equally rewarding nonrevenge opportunity. Specifically, participants had the opportunity to take money from an opponent or take money from a neutral bank. Because Experiment 1 had both a positive condition (revenge trials) and negative condition (aggravation trials), it may not have allowed us to compare the unique role of approach-motivated anger alone on revenge, relative to another approach-motivated positive condition. Thus, Experiment 2 only created approach-motivated states of either winning money from a bank or from the offending opponent. This allowed for the comparison between two potential wins: one motivated by revenge, and the other unmotivated by revenge. Together, Experiment 2 allowed us to parse out more directly how approach-motivated anger associated with revenge relates to reward seeking.

To test this, Experiment 2 used a different variation of the MAD paradigm. After the same insult manipulation used in Experiment 1, participants were told that they were going to participate in a reaction time game against their opponent where they could win money from a variety of sources. Participants were then told that they were randomly assigned to begin the game with no money, while the insulter was given $10.00. Finally, participants were told that in some trials, participants could win the trial and take money from their opponent (revenge condition). In other trials, participants could win the trial and win money from a neutral bank (bank condition). Thus, in this version of the MAD paradigm, participants partook in two positive conditions in which both awarded money, but should invoke different levels of approach motivation (since participants could seek revenge against their opponent in one condition, while they could not seek revenge in the other condition).

Approach-motivated anger should be greatest when one is able to rectify an angering event (Harmon-Jones et al., 2003). Therefore, participants should experience the most approach motivation when they are able to win the opportunity to get revenge by taking money from the opponent, as opposed to simply winning money from a neutral bank. Thus, approach motivation was predicted to increase outcome monitoring sensitivity. Specifically, we predicted that the RewP would be larger to win feedback following both revenge trials and bank trials than win feedback following no-consequence trials. More importantly, we predicted that the RewP would be larger to win feedback following revenge trials than win feedback following bank trials. Approach-motivated anger should increase outcome monitoring sensitivity when winning the ability to win money and resolve the source of anger.

4.1 | Methods

4.1.1 | Participants

We conducted a second power analysis utilizing the results of Experiment 1. More specifically, we used the partial-eta squared effect size of .05 (as was found in Experiment 1). We also used the more customary power value of 80%. Keeping all other parameters constant with the power analysis from Experiment 1, we determined that a sample size of 33 participants was sufficient. However, given that we did not pilot test the changes between Experiment 1 and Experiment 2 made to the MAD paradigm, we sought to run a similar number of participants in the current study as Experiment 1. Sixty-three right-handed individuals participated in exchange for partial course credit. Seven participant's EEG data was lost due to computer malfunction and were excluded. This left a total sample of 56 participants (before exclusions due to no increase in frontal asymmetry scores).

4.1.2 | Procedures

All procedures preceding the reaction time game replicated those of Experiment 1. However, to investigate the unique role of approach-motivated anger in reward processing, we used a different variation of the MAD paradigm. In this variation, participants were given the opportunity to win money if they were faster than their opponent in a reaction time game (see Figure 8). On revenge trials, if the participant won, they had the opportunity to take up to $0.15 from their opponent (1 = *$0.00*, 6 = *$0.15*; increments of 3 cents). If they lost, participants proceeded to the next trial.

Furthermore, so that participants would know that the other opponent would not be able to retaliate, aggravation trials were replaced with bank trials. Thus, square cues now represented bank trial cues. On these trials, following the goal-directed task (flanker response), participants received feedback indicating whether they did or did not win on that trial. More specifically, participants were presented with a white square with either a green up arrow or a red down arrow, indicating win or loss feedback, respectively. If the participant won, they had the opportunity to take up to $0.15 from a bank (1 = *$0.00*, 6 = *$0.15*; increments of 3 cents).[8] If they lost, participants proceeded to the next trial. All other aspects of the MAD paradigm were similar to Experiment 1.

The game lasted for approximately 50 min. During debriefing, all participants reported that they were engaged throughout the entirety of the game, and no participants reported being fatigued.

After the game, participants completed the PANAS-X (Watson & Clark, 1999) a second time. Furthermore, participants rated how they felt during each of the three trial cues and each of the six possible feedback cues presented in the MAD paradigm on a scale of 1 (*no emotion*) to 9 (*strongest feeling*; Ekman et al., 1980). Similar to Experiment 1, words assessing similar affective responses were averaged across picture type to form indices for excitement (excited and enthusiastic; Cronbach's alpha = .70) and anger (angry and mad; Cronbach's alpha = .74) toward each of the trial cues and trial feedback ratings

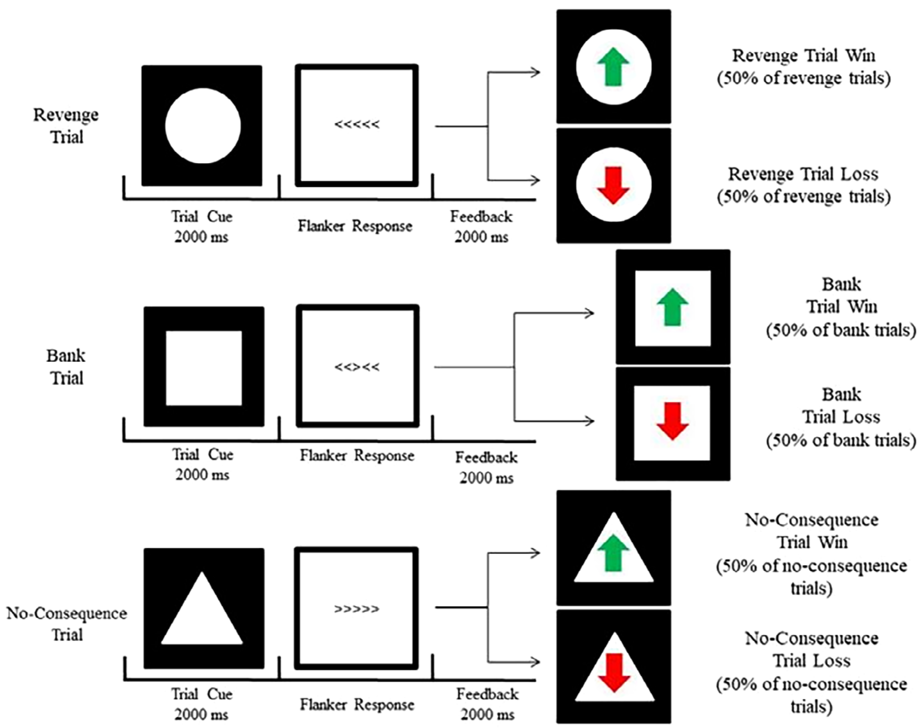

FIGURE 8 Experiment 2 example trials. Between the trial cue and flanker response, there was an ISI of 500 ms. Between the flanker response and feedback, there was an ISI of 500 ms. The intertrial intervals were 4,000 ms. A black screen was presented during all ISI's and ITI's

separately. Ratings data with no responses were removed from analyses, leading to variations in degrees of freedom for analyses.

4.1.3 | EEG processing

All EEG data collection and preprocessing steps were identical to Study 1.

4.1.4 | Frontal asymmetry assessment

Frontal asymmetry assessment was identical to Study 1. The difference between left and right frontal alpha activity was maximal at the index of all three pairs of frontal sites (Cronbach's alpha for the first baseline period = .990; Cronbach's alpha for the second baseline period = .967). Similar to Experiment 1, we excluded from analyses those participants who failed to show an increase in left frontal alpha asymmetrical activation after the anger induction. Specifically, data from 21 participants failed to show an increase in left frontal alpha asymmetry. This left 35 participants for hypothesis testing (see Table 6 for sample characteristics).[9]

TABLE 6 Demographic characteristics of full sample and sample for testing in Experiment 2

Variable	Full sample	Sample for testing
Gender		
Female	68.3	62.9
Male	31.7	37.1
Age	18.76 (0.93)	18.74 (0.82)
Race		
White	84.1	85.7
African-American	9.5	5.7
Other	6.3	8.6
Ethnicity		
Hispanic	14.3	11.4
Non-Hispanic	85.7	88.6

Note: Values are percentage or mean (*SD* in parentheses). Full sample demographics $n = 63$; Sample for testing demographics $n = 35$.

4.1.5 | ERP assessment

ERP assessment was identical to Experiment 1. Twelve trials were entered into each of the average waveforms for revenge trial wins, revenge trial losses, bank trial wins, bank trial losses, no-consequence trial wins, and no-consequence trial losses. Based on past research, the RewP mean amplitude was assessed at site Cz within a window of 250–350 ms after feedback onset, because this electrode site and time window had the greatest difference between wins and losses (Baker & Holroyd, 2011; Foti et al., 2011; Threadgill & Gable, 2016).

4.1.6 | Experimental design and statistical analysis

All data were analyzed with STATISTICA 7 (version 7.1, StatSoft, 2008) using either dependent-sample *t*-tests or repeated-measures analysis of variance (ANOVA). The criterion of statistical significance for all analyses was $p < .05$. Post hoc testing was conducted using Fisher's LSD. Means and *SD*s for all variables are presented in Table 7. Full expanded hypotheses for all manipulation checks can again be found in the Supplementary Materials. Correlations between all main variables of interest are presented in Supplementary Tables S4-S6.

TABLE 7 Means and *SD*s for all variables in Experiment 2

Variable	Revenge trial	Bank trial	No-consequence trial
Trial Cue rating			
Excitement	5.02 (2.39)	4.69 (2.13)	2.64 (1.07)
Anger	2.26 (1.93)	1.69 (1.03)	1.59 (1.03)
Win feedback rating			
Excitement	6.39 (2.00)	5.61 (2.07)	3.91 (2.07)
Anger	1.37 (0.47)	1.42 (0.78)	1.44 (0.94)
Loss feedback rating			
Excitement	1.50 (1.07)	1.44 (0.70)	1.61 (1.27)
Anger	4.48 (2.74)	4.02 (2.41)	2.98 (2.32)
Logged RT	6.42 (0.21)	6.43 (0.22)	6.48 (0.24)
Raw RT	661.74 (160.08)	665.81 (160.66)	718.19 (198.88)
RewP			
Win feedback	16.69 (8.07)	14.25 (8.98)	11.89 (8.63)
Loss feedback	12.17 (7.89)	13.09 (7.16)	10.80 (9.12)

*Note: SD*s are in parentheses.

TABLE 8 Statistical analyses for emotion ratings to trial cues in Experiment 2

Factors (df)	F	p	η_p^2
Excitement (2, 56)	14.16	<.001	.34
Anger (2, 52)	2.39	.102	.08

Abbreviation: df, degrees of freedom.

5 | RESULTS

5.1 | Baseline affect

A dependent-sample t-test indicated that participants reported being significantly more angry following the insult ($M = 1.56$, $SD = 0.93$), relative to a baseline state ($M = 1.01$, $SD = 0.08$), $t(34) = 3.63$, $p = .001$, $d = 0.61$.

5.2 | Trial emotion ratings

5.2.1 | Emotion ratings to trial cues

A one-way (trial type: revenge vs. bank vs. no-consequence) repeated-measures ANOVA examining excitement ratings to the trial cues was significant (see Table 8). Post hoc analyses revealed that participants were more excited by the revenge trials ($t[28] = 4.21$, $p < .001$, $d = 0.78$) and bank trials ($t[28] = 4.50$, $p < .001$, $d = 0.84$) than the no-consequence trials. There was no difference in excitement ratings to revenge and bank trial cues, $t(28) = 0.78$, $p = .502$, $d = 0.14$. These results suggest participants were most excited by the revenge and bank trials.

A one-way (trial type: revenge vs. bank vs. no-consequence) ANOVA examining anger ratings to the trial cues was not significant.

5.2.2 | Emotion ratings to feedback cues

Affect ratings to the feedback cues were examined using a 2 (affective state: excitement vs. anger) × 3 (trial type: revenge vs. bank vs. no-consequence) × 2 (outcome: win vs. loss) repeated-measures ANOVA. This interaction was significant (see Table 9). This three-way interaction was unpacked by examining the 3 (trial type) × 2 (outcome) interaction for excitement ratings and for anger ratings.

For excitement ratings, results indicated that there was a significant trial type by outcome interaction (see Table 9). A one-way (trial type: revenge vs. bank vs. no-consequence) ANOVA examining excitement ratings to win feedback cues was significant. Post hoc analyses revealed that participants experienced more excitement to both revenge trial wins ($t[27] = 4.39$, $p < .001$, $d = 0.83$) and bank trial wins ($t[27] = 3.64$, $p < .001$, $d = 0.69$) than no-consequence trial wins. Importantly, revenge trial wins elicited more excitement than bank trial wins, $t(27) = 2.17$, $p = .050$, $d = 0.41$. The one-way (trial type: revenge vs. bank vs. no-consequence) ANOVA examining excitement ratings to loss feedback cues was not significant.

TABLE 9 Statistical analyses for emotion ratings to feedback cues in Experiment 2

Factors (df)	F	p	η_p^2
Affective state × trial type × outcome (2, 52)	23.54	<.001	.49
Excitement			
Trial type × outcome (2, 52)	20.27	<.001	.44
Win (2, 52)	21.47	<.001	.45
Loss (2, 52)	0.31	.736	.01
Anger			
Trial type × outcome (2, 52)	7.83	.001	.23
Win (2, 52)	0.21	.811	.01
Loss (2, 52)	6.59	.003	.20

Abbreviation: df, degrees of freedom.

For anger ratings, results indicated that there was a significant trial type by outcome interaction (see Table 9). A one-way (trial type: revenge vs. bank vs. no-consequence) ANOVA examining anger ratings to win feedback cues was not significant. However, the one-way (trial type: revenge vs. bank vs. no-consequence) ANOVA examining anger ratings to loss feedback cues was significant. Post hoc analyses revealed that participants experienced more anger to both revenge trial losses ($t[26] = 3.08$, $p = .005$, $d = 0.51$) and bank trial losses ($t[26] = 2.41$, $p = .019$, $d = 0.57$) than no-consequence trial losses. There was no difference in self-reported anger between revenge and bank trial loss feedback, $t(26) = 1.31$, $p = .202$, $d = 0.22$.

5.3 | Flanker response reaction times

Incorrect flanker responses were removed from analysis (revenge trials: 86.35% retained; bank trials: 84.91% retained; no-consequence trials: 83.48% retained). Reaction times were logarithmically transformed. A one-way (trial type: revenge vs. bank vs. no-consequence) ANOVA revealed a nonsignificant, but marginal, main effect of flanker response reaction time, $F(2, 54) = 2.54$, $p = .089$, $\eta_p^2 = .09$. Post hoc analyses revealed that reaction times to the flanker response on revenge trials were faster than reaction times on no-consequence trials, $t(27) = 1.80$, $p = .022$, $d = 0.34$. Reaction times to the flanker response on bank trials were marginally faster than reaction times on no-consequence trials, $t(27) = 1.59$, $p = .082$, $d = 0.30$. There were no differences in flanker response reaction time between revenge trials and bank trials, $t(27) = 0.73$, $p = .563$, $d = 0.14$. Both revenge trials and bank trials sped reaction times, as compared to no-consequence trials.

5.4 | The reward positivity

To examine differences in RewP amplitude between trial types, we conducted a 3 (trial type: revenge vs. bank vs. no-consequence) × 2

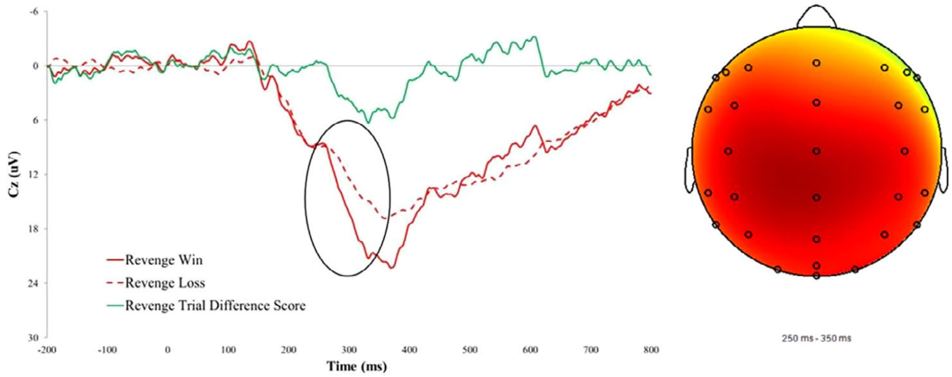

FIGURE 9 Left: ERP waveforms for win and loss feedback during revenge trials in Experiment 2, as well as the difference score between revenge trial wins and revenge trial losses (win minus loss) at site CZ. The RewP component is circled. Note that negative is plotted up by convention. Right: Scalp topography displaying the difference between wins and losses

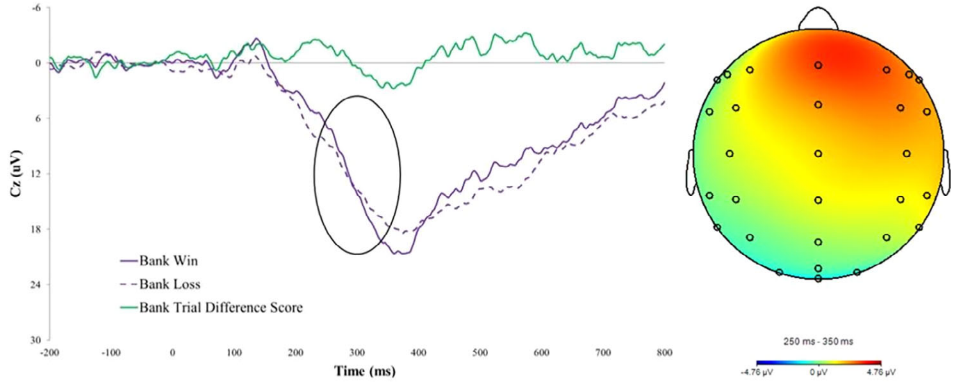

FIGURE 10 Left: ERP waveforms for win and loss feedback during bank trials in Experiment 2, as well as the difference score between bank trial wins and bank trial losses (win minus loss) at site CZ. The RewP component is circled. Right: Scalp topography displaying the difference between wins and losses

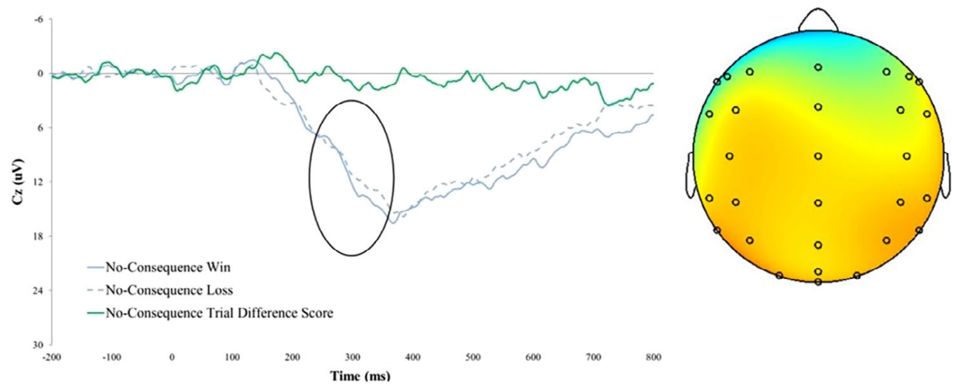

FIGURE 11 Left: ERP waveforms for win and loss feedback during no-consequence trials in Experiment 2, as well as the difference score between no-consequence trial wins and no-consequence trial losses (win minus loss) at site CZ. The RewP component is circled. Right: Scalp topography displaying the difference between wins and losses

(outcome: win vs. loss) repeated-measures ANOVA. Results indicated that there were significant main effects of both trial type and feedback. Finally, there was a nonsignificant interaction (but the interaction bordered on significant; see Figures 9-13 and Table 10).[10]

Based on hypotheses, we wanted to investigate how condition influenced win and loss feedback using a series of one-way ANOVAs. For RewP amplitudes to win feedback, a one-way (trial type: revenge vs. bank vs. no-consequence) ANOVA was significant. Post hoc analyses revealed that the RewP to revenge trial wins was larger than the RewP to no-consequence trial wins, $t(32) = 4.63$, $p < .001$, $d = 0.81$. Additionally, the RewP to bank trial wins was larger than the RewP to no-consequence trial wins, $t(32) = 1.78$, $p = .047$, $d = 0.31$. Most importantly, the RewP to revenge trial wins was larger than the RewP to bank trial wins, $t(32) = 2.18$, $p = .041$, $d = 0.38$. Together, these results suggest that revenge trial wins elicit larger RewP amplitudes than both bank and no-consequence trial wins, and bank trial wins elicit larger RewP amplitudes than no-consequence trial wins.

For RewP amplitudes to loss feedback, a one-way (trial type: revenge vs. bank vs. no-consequence) repeated-measures ANOVA was not significant.

Because the RewP has traditionally been examined by comparing amplitudes during win feedback to amplitudes during loss feedback, we conducted a dependent-sample *t*-test within each trial type. Revenge trial wins elicited a larger RewP than revenge trial losses, $t(32) = 4.22$, $p < .001$, $d = 0.73$. There were no differences in RewP amplitudes between bank trial wins and bank trial losses ($t(32) = 0.81$,

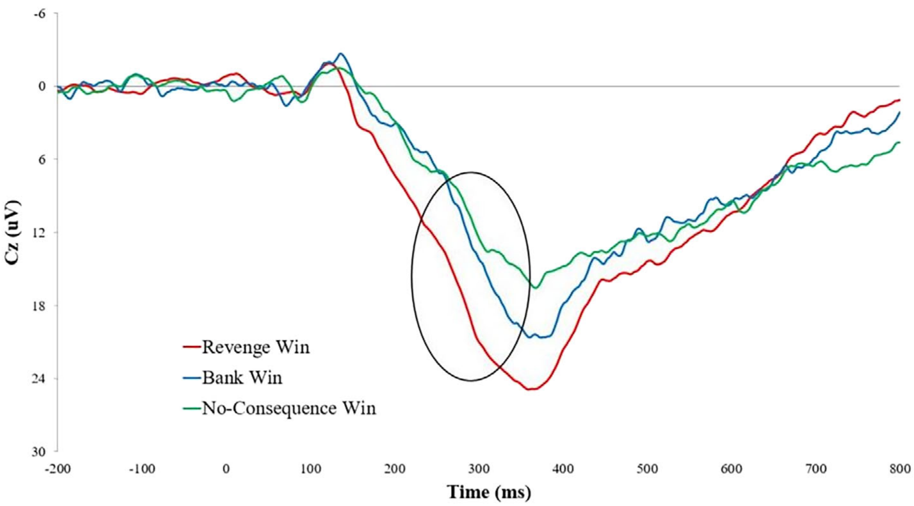

FIGURE 12 ERP waveforms for win feedback during revenge, bank, and no-consequence trials in Experiment 2 at site CZ

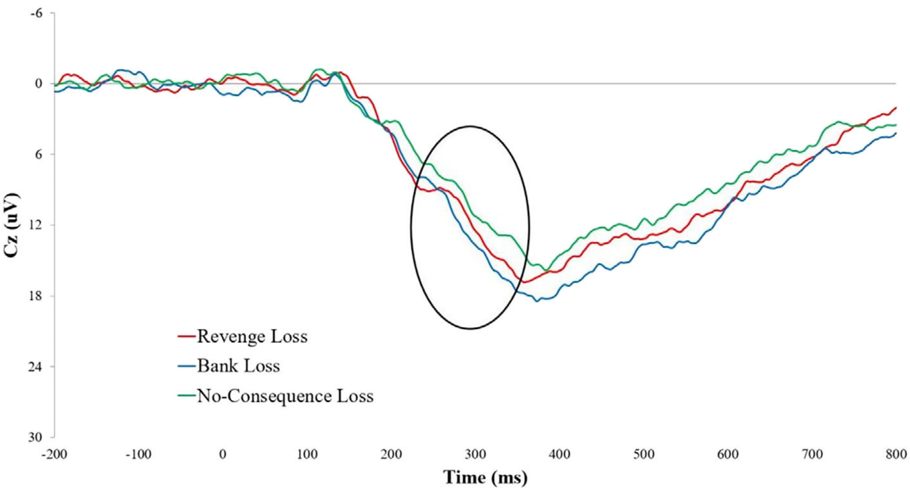

FIGURE 13 ERP waveforms for loss feedback during revenge, bank, and no-consequence trials in Experiment 2 at site CZ

TABLE 10 Statistical analyses for the reward positivity in Experiment 2

Factors (df)	*F*	*p*	η_p^2
Trial type (2, 64)	6.36	.003	.17
Outcome (1, 32)	6.35	.017	.17
Trial type × outcome (2, 64)	3.05	.054	.09
Trial type – Wins (2, 64)	8.45	<.001	.21
Trial type – Losses (2, 64)	1.74	.183	.05

Abbreviation: df, degrees of freedom.

p = .424, d = 0.14) or between no-consequence trial wins and no-consequence trial losses (t(32) = 0.83, p = .412, d = 0.83).[11]

5.5 | Discussion for experiment 2

Experiment 2 revealed that, when angry, participants experienced more excitement to both revenge and bank trial cues than no-consequence trial cues. This suggests that participants were experiencing approach-motivated affective states during the pursuit of rewards. Additionally, both revenge and bank trial win feedback elicited more excitement than no-consequence trial win feedback. Importantly, revenge trial win feedback elicited more excitement than bank trial win feedback. This suggests that participants experienced the most approach motivation to feedback in which anger could be ameliorated. Revenge and bank trial loss feedback elicited more anger than no-consequence trial loss feedback. This suggests that participants experienced approach-motivated affective states to angering feedback. Behavioral results based on flanker task reaction times support that participants were approach-motivated by the revenge and bank conditions. Participants were faster to flanker responses following revenge and bank trial cues than no-consequence trial cues. Together with self-reported emotion, these results indicate that participants experienced increased approach-motivated affect in revenge trials, followed by bank trials and no-consequence trials, respectively.

RewP amplitudes were larger after revenge trial win feedback than after revenge trial loss feedback. Consistent with past work, these results suggest that the RewP is more sensitive to win feedback than loss feedback, particularly in approach-motivated conditions. RewP amplitudes were also larger after both revenge trial win feedback and bank trial win feedback than no-consequence trial win feedback. These results suggest that approach-motivated states associated with a goal evoked larger RewPs than no-consequence states. Most importantly, revenge trial win feedback elicited larger RewP amplitudes than bank trial win feedback. This suggests that situations in which the greatest amount of approach-motivated affect should be present enhanced RewPs more than other approach-motivating situations.

The present results found no difference in the RewP between wins and losses in the bank condition. Past research has found that the RewP reflects the binary evaluation of feedback as either positive or negative (Hajcak et al., 2006; Proudfit, 2015). However, Kujawa, Smith, Luhmann, and Hajcak (2012) found that the RewP was larger to positive outcomes than negative outcomes when accounting for the global context in which the win and loss is taking place. In their study, the RewP did not show differences between wins and losses for every trial type. Instead, the difference between wins and losses was only seen when the outcome represented the best possible outcome across all trial types. Thus, it could be the case that the RewP could be tracking the global context in which the feedback is occurring. As compared to the differences in revenge trial wins and losses, the bank and no-consequence trials were not as rewarding. In the context of Experiment 2, it is likely that participants did not show the expected differences between wins and losses in the bank condition because they found wins in the revenge condition (where they could both win money *and* get revenge) to be more rewarding than simply winning money in the bank condition. Rather than simply tracking whether or not the feedback was positive or negative, participants also tracked the outcome in relation to all other possible outcomes.

6 | GENERAL DISCUSSION

Results from two experiments revealed that approach-motivated anger enhanced the RewP to revenge opportunities. Importantly, these effects occurred regardless of outcome valence. These results are consistent with the idea that the RewP (and, more broadly, feedback monitoring in general) is not strictly due to whether feedback is positive or negative, but, rather, incorporates the motivational salience of outcomes. Outcomes higher in motivational salience evoke larger RewPs, irrespective of outcome valence.

The finding that greater RewP amplitudes to revenge trial win feedback than revenge trial loss feedback in those who are made angry by an insult manipulation is in line with past work finding that approach-motivated positive win feedback elicits a larger RewP than loss feedback (Threadgill & Gable, 2016, 2018b). However, in Experiment 1, there was no difference between win feedback and loss feedback for aggravation trials. In Experiment 2, there was no difference between win feedback and loss feedback for bank trials. This falls in line with the hypothesis that the RewP reflects general motivational salience, not outcome valence (Huang & Yu, 2014; Pfabigan, Alexopoulos, Bauer, & Sailer, 2011). In the current experiments, all included individuals were angry at their opponent, due to the insulting feedback on the essay. For revenge trials, participants were motivated to win the reward of blasting the insulter with a loud noise (Experiment 1) or taking the insulter's money (Experiment 2). It is likely the case that participants did not exhibit differences between win and loss feedback during aggravation trials (Experiment 1) or bank trials (Experiment 2) because these conditions were not the most motivationally salient outcomes. In Experiment 1, participants would rather win the opportunity to blast their opponent with a loud noise than be blasted with a loud noise. In Experiment 2, while participants did report more excitement to winning money from the bank than winning in a no-consequence trial, participants also reported experiencing more excitement to winning money from the offending opponent than winning money from the bank. These results suggest that winning money from the bank was less motivationally salient than winning money as revenge. Together, results suggest that more motivationally salient outcomes, not outcome valence, elicited in differences between neural responses to wins and losses.

In Experiment 1, participants experienced approach motivation during aggravation trials by beating the insulter and receiving winning feedback. When participants received win feedback in aggravation trials, they experienced approach-motivated excitement, because they blocked the insulter from winning a reward. Participants were also approach-motivated when they lost during aggravation trials, because they were angered by the injustice of losing to an opponent who had previously insulted them. Participants were already angry at the opponent for insulting the participant via the disparaging feedback on the essay. Aggravation trials increased approach-motivated anger because not only did the opponent insult the participant via disparaging feedback on the essay, but the insulter was also able to blast the participant with a loud noise. Aggravation trial win feedback led to approach-motivated positive affect (excitement), while aggravation trial losses led to approach-motivated negative affect (anger). Approach motivation enhanced RewP amplitudes to both wins and losses, relative to a no-consequence state, suggesting that motivational salience, not feedback outcome, drove reward processing.

Experiment 2 built on the results of Experiment 1 by removing the possibility for participants to experience an increase in approach-motivated anger via the aggravation trials. In Experiment 2, participants who were made angry by the insult manipulation experienced approach motivation during bank trials by beating the insulter and receiving winning feedback. When participants received win feedback in bank trials, they experienced approach-motivated excitement, because they won money, even though the money was from a general bank and not their opponent. As revealed by both excitement ratings to the trial outcomes and RewP amplitudes, participants expressed greater excitement and displayed larger RewP amplitudes to revenge trial wins than bank trial wins. Notably, this occurred even though participants reported experiencing greater excitement and exhibiting larger RewP amplitudes to bank trial wins than no-consequence trial wins. Wining money via revenge appears to elicit more approach-motivated affect than simply winning money from a general bank.

Interestingly, in Experiment 2, revenge trial wins elicited larger RewP amplitudes than revenge trial losses, while there was no difference in RewP amplitude between wins and losses in the bank condition. This likely occurred because past research has found that outcome evaluation occurs within the overall context in which feedback is presented (Kujawa et al., 2012; Van den Berg, Shaul, Van der Veen, & Franker, 2012). It is likely the case that bank trials did not elicit enough approach motivation to cause a significant difference in RewP amplitudes between wins and losses, because other trials (i.e., revenge trials) both rewarded the participant with money and punished an offending opponent. Even though bank trials were both rated as more exciting and elicited marginally faster reaction times to the flanker response than no-consequence trials (which suggests that approach motivation was increased, relative to no-consequence trials), it seems that revenge trials, because they were the most motivationally salient, elicited differences in the RewP between wins and losses, while bank trials did not. Thus, while participants did experience approach motivation during bank trials, participants experienced the most approach motivation when they were able to win money and punish the insulter at the same time.

6.1 | The reward positivity and approach motivation

The current research was based on past evidence linking the RewP with approach motivation (Threadgill & Gable, 2016, 2018b). Consistent with past work, individuals who were made angry by the insult manipulation exhibited larger RewPs to feedback while in approach motivated states (Experiment 1). Furthermore, in Experiment 2, we isolated the unique role of approach motivation on the RewP by giving participants the opportunity to win money from either an offending opponent or a neutral third-party bank. Results indicated that individuals exhibited the largest RewP during the most motivationally salient outcome: both winning money and gaining the opportunity for revenge by punishing an offending opponent.

The current results are the first to demonstrate that negative approach-motivated affects increase feedback processing sensitivity. Past research has focused on the role of positive approach-motivated states on reward processing. By showing that negative approach-motivated affects increase the RewP, results suggest that approach motivation, not outcome valence, is driving reward sensitivity. Building on past work, it appears that approach motivation, regardless of valence, enhances processing of feedback indicating successful goal pursuit.

6.2 | Anger, revenge, and pleasure

The present work provides further evidence for the role of both anger and pleasure in revengeful behaviors. Revenge is an act driven by the desire to see some transgressor suffer (Zaibert, 2006). Of key importance is the notion that revenge (usually) occurs in response to some aversive event (Anderson & Bushman, 2002). Presumably, the perceived injustice arouses negative affects such as anger, leading to an attempt to resolve the anger-inducing event (Harmon-Jones & Sigelman, 2001). This behavior may have arisen as an evolutionary adaptation, in that aggressive behaviors from revenge are attempts to increase the likelihood of survival (Olivier & Young, 2002). Anger emanates in response to some obstacle, motivating an organism to find ways to remove that impediment. In the current experiments, participants experienced a negative situation by receiving insulting feedback from an opponent. Participants were then given the opportunity to get revenge against their opponent by either blasting them with loud noises (Experiment 1) or taking money from them (Experiment 2). Thus, participants were primed to seek revenge against their insulter as a result of their anger, suggesting that approach-motivated anger motivated revenge seeking. The present results provide evidence that revenge is used as a tool to rectify angering situations.

Individuals often partake in anger-driven revengeful acts because they believe these behaviors will lead to a positive experience or positive feelings (Bushman, 2002; Chester & DeWall, 2017). This increase in positive affect after an aggressive reaction occurs because the individual believes that justice has been delivered to the transgressor (Frijda, 1994). The current results provide the first evidence that individuals who are made angry by an instigator, for at least a moment, exhibit neural signatures associated with pleasure (and, therefore, likely actually *experience* increases in pleasure) when winning the opportunity to get revenge against their transgressor. By using neurophysiological methods capable of measuring momentary fluctuations in emotional state, the present results found that participants who were angry exhibited increases in neural signatures of reward processing when winning the opportunity to get revenge against an offending individual. Thus, it seems likely that approach-motivated anger leads to revengeful acts out of a desire to experience pleasure from seeing the transgressor suffer. Furthermore, the current experiments provide evidence that individuals actually experience more pleasure when winning the opportunity to seek revenge against an offending opponent.

Additionally, the current research addresses an important lacuna in past research examining the relationship between revenge, pleasure, and neural processing. While past work using functional magnetic resonance imaging (fMRI) has found that acts of revenge activate regions of the brain associated with reward processing, such as the dorsal striatum (de Quervain et al., 2004), ventral striatum (Chester & DeWall, 2018), and nucleus accumbens (Chester & DeWall, 2016), the present research examines the momentary neural responses to winning the opportunity to aggress against an offending opponent. The present experiments provide evidence that individuals who are angry at a transgressor exhibit neural signatures of pleasure immediately after winning the opportunity to seek revenge against an offending opponent. Crucially, this occurred following the activation of approach-motivated anger, which motivated individuals to seek revenge against their transgressor. By showing that anger, a negative affect associated with approach motivation, increases reward sensitivity to the motivationally salient outcome of winning the opportunity for revenge, the present research provides further support for the proposition of revenge as pleasurable.

6.3 | Limitations and future directions

One of the main issues in emotion research is that a specific emotion manipulation often elicits a multitude of different emotions (Ekman, 1984; Ekman et al., 1980). Participants are not always able to express the magnitude of each emotion felt during a specific emotion manipulation via self-report questionnaires (Moore & Oaksford, 2002). While self-report questionnaires do add important information about the emotional states experienced toward a stimulus, self-reported emotion by itself can be an unreliable assessment of emotion (Stemmler, 2003). In addition, measures of self-report can disrupt the emotional state.

In the current experiments, the target emotion of anger after being insulted was assessed using frontal asymmetry, a well-validated psychophysiological signature of anger (Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Shackman et al., 2006). While left frontal asymmetry has been found to relate to other psychological processes besides anger (for a review, see Gable et al., 2018; Harmon-Jones & Gable, 2018; Harmon-Jones, Gable, & Peterson, 2010), a wealth of research has demonstrated a relationship between left frontal asymmetry and an insult manipulation (Harmon-Jones, Peterson, & Harris, 2009; Harmon-Jones & Sigelman, 2001; Jensen-Campbell et al., 2007; Kelley et al., 2015; Verona et al., 2009). In both experiments, participants were excluded on the basis of neurophysiological markers indicative of approach-motivated anger, measured independently of the main variable of interest. Utilizing frontal asymmetry allowed us to focus on participants who experienced approach-motivated anger in response the insult and were motivated to seek revenge on their opponent. This allowed for a more precise examination of how approach-motivated anger affects the RewP. As with any exclusion, this had a decrease on statistical power to detect an effect. However, because all included participants were strongly displaying approach-motivated anger, this likely increased the strength of the revenge and aggravation manipulations.

Another limitation is that the paradigm took approximately 50 min to complete. Although none of the participants reporting fatigued by the task in either study, it is likely the case that participants were less energetic by the end of the task than at the beginning. Now that these studies have demonstrated the validity of the MAD to measure approach-motivated revenge, future studies might benefit from shortening the task to be completed more quickly.

The present research provides a novel task by which to examine momentary positive reactions to revengeful aggression. Much research examining the relationship between anger, pleasure, and revengeful aggression have used self-report measures to examine the pleasurable aspects of revenge, which may not always be reliable. Furthermore, other aggression paradigms, such as the Taylor Aggression Paradigm, combine outcomes that result in aggression (i.e., winning the opportunity to aggress against an opponent or losing that results in the opponent aggressing against the participant) into a single trial type. The current experiments provide a new aggression paradigm, known as the MAD paradigm, by which future research can compare the momentary emotional reactions to winning the opportunity to seek revenge to the momentary emotional reactions to losing that results in the opponent aggressing against the participant. Future research can use the present paradigm to understand the underlying reactions to every aspect of revenge, such as the pursuit of revenge, the actual obtainment of the opportunity to seek revenge, and the actual process of partaking in revengeful behaviors.

The current article focused on looking at provoked acts of aggression and not unprovoked acts of aggression. Because all participants were provoked in the current experiments, there is not an unprovoked comparison group. As such, the current experiments cannot compare aggression against an offending opponent from aggression against a nonoffending opponent. Future research could also use a version of the MAD paradigm with neutral or positive feedback to the essay manipulation as a between-subjects factor to examine how different emotional states relate to revenge or, more broadly, general opportunities for aggression.

Furthermore, the MAD paradigm is versatile, in that aspects of the design can be manipulated depending on the population being studied. For example, the current version of the MAD paradigm uses negative feedback about an essay written by the participant, ostensibly from another participant. Researchers studying young children could change the specific anger provocation of the MAD paradigm to a more developmentally appropriate anger provocation that is easier for children to comprehend (such as Cyberball; Chester & DeWall, 2017).

The MAD paradigm should be useful to study clinical populations who exhibit persistent antisocial behavior, including psychopathy and antisocial personality disorder. This is especially pertinent considering that that the National Institute of Mental Health's Research Domain Criteria (RDoC) initiative accentuates the need to understand individual differences in psychological disorders via core neurobiological systems (Cuthbert & Insel, 2013; Sanislow et al., 2010). By understanding the neural underpinnings of maladaptive behaviors within these clinical populations, researchers may be able to understand what neural processes are occurring during the actual perpetuation of these misanthropic behaviors, and, therefore, provide a better understanding of cognitive functioning within these clinical populations.

6.4 | Conclusions

Recent research has found that the RewP is sensitive to approach-motivated states that occur during the pursuit of a goal (Meadows, Gable, Lohse, & Miller, 2016; Threadgill & Gable, 2016, 2018b). The current experiments found that anger, a high intensity approach-motivated negative affect, enhances the RewP, especially when that goal brings about revenge. RewP amplitudes were larger to feedback indicating the offending individual was rewarded due to an increase in aggravation. Together, these results suggest that the RewP reflects an active performance monitoring system influenced by approach-motivated goal states, regardless of affective valence. Anger generates approach-motivated action tendencies, which influences action-monitoring processes associated with the RewP (Brehm, 1999; Carver & Harmon-Jones, 2009). Organisms are driven to approach a specific outcome, enhancing performance monitoring and feedback processing in order to potentially aid future goal pursuit.

The present results suggest that anger, a high intensity approach motivated negative affect, amplifies the RewP when winning the ability to seek revenge and prevent further aggravation. Past work has typically only found that approach motivation enhances processing of winning feedback, confounding valence and motivation (Threadgill & Gable, 2016, 2018b). However, the present work's unique experimental design allowed us to evoke negative approach-motivated affect, finding that approach motivation in general enhances feedback processing to revenge opportunities, regardless of outcome valence. This is in line with a growing body of work suggesting that motivational salience, rather than valence, drives neural correlates of reward processing (Pfabigan et al., 2015).

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CONFLICT OF INTERESTS

The authors declare no competing financial interests.

DATA AVAILABILITY STATEMENT

All experimental protocols, example documents, stimuli, computer scripts, and data for both experiments are available online at https://osf.io/7v94a/ (doi: 10.17605/OSF.IO/7V94A).

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ENDNOTES

[1] All procedures and analyses for Experiment 1 were preregistered to a Thesis committee at the University of Alabama prior to data collection.

[2] We did not assess emotional states via self-report after the delivery of the insulting feedback for two reasons. First, asking participants to reevaluate their emotional state after the feedback delivery likely would have altered their emotional state in a way that they would have felt less anger (Hauser, Ellsworth, & Gonzalez, 2018). Second, previous research using this paradigm has found that insulting feedback increases anger, relative to a neutral condition, while not increasing fear, distress, sadness, and happiness (Harmon-Jones et al., 2004; Harmon-Jones & Sigelman, 2001). For these reasons, we did not assess emotional states via self-report after the delivery of the insulting feedback. Rather, anger was assessed as increases in left frontal activation following the insulting feedback, as compared to the baseline measurement before the delivery of the insult.

[3] Past work has measured resting left frontal asymmetry using an 8 min baseline period (Neal & Gable, 2017). However, both shortened baseline periods demonstrated excellent reliability that is similar to past work (Neal & Gable, 2017, found that resting frontal asymmetry over an 8 min baseline period demonstrated Cronbach's alpha of .97).

[4] While much research has examined the RewP at site FCz, some work has argued that there may be variance in the topography of the maximal RewP (Krigolson, 2018). Indeed, some work has found that the RewP is maximal at site Fz (Van den Berg, Franken, & Muris, 2011), while others have found that the RewP is maximal at site Cz (Holroyd, Pakzad-Vaezi, & Krigolson, 2008; Threadgill & Gable, 2016, 2018b).

[5] An independent sample *t*-test indicated that excluded participants ($n = 16$, $M = -0.11$, $SD = 0.28$) had a significantly smaller change in relative left frontal alpha activity following the anger induction than the non-excluded participants ($n = 44$, $M = 0.22$, $SD = 0.20$), $t(58) = 5.05$, $p < .001$. A one-sample *t*-test indicated that the remaining participants exhibited a significant increase in relative left frontal alpha activity following the anger induction, $t(43) = 7.22$, $p < .001$. Furthermore, to ensure that we did not bias the selected sample to show RewP differences across conditions, we conducted correlations between relative left frontal alpha activity and the RewP to revenge trial win feedback for both participants included for analysis and participants excluded for analysis. Both correlations were not significant, p's > .689.

[6] A 3 (trial type) x 2 (outcome) repeated-measure ANOVA examining the RewP that included all participants, including those who were originally excluded, did not reveal a significant interaction, $F(2, 108) = 0.97$, $p = .382$, $\eta_p^2 = .02$.

[7] Because the RewP can potentially have strong temporal overlap with the P3 (Holroyd, Nieuwenhuis, Yeung, & Cohen, 2003; Novak & Foti, 2015), we also examined the P3 to feedback. Based on past research, the P3 was assessed at site CZ within a window of 350–600 ms after feedback onset (Threadgill & Gable, 2016; Weinberg, Luhmann, Bress, & Hajcak, 2012). A 3 (trial type: revenge vs. no-consequence vs. aggravation) x 2 (outcome: win vs. loss) repeated-measures ANOVA for the P3 did not reveal a significant interaction, $F(2, 82) = 1.60$, $p = .208$, $\eta_p^2 = .04$.

[8] A dependent-sample *t*-test comparing the amount of money taken from the offending opponent ($M = 13.33$, $SD = 3.08$) and the amount of money taken from the bank ($M = 13.80$, $SD = 2.38$) was not significant, $t(25) = 1.32$, $p = .199$, $d = 0.26$, 95% CI [−0.13, 0.65]. Participants took the same amount of money, regardless of the source.

[9] An independent sample *t*-test indicated that excluded participants ($n = 21$, $M = -0.12$, $SD = 0.08$) had a significantly smaller change in relative left frontal alpha activity following the anger induction than the non-excluded participants ($n = 36$, $M = 0.15$, $SD = 0.12$), $t(55) = 9.02$, $p < .001$. A one-sample *t*-test indicated that the remaining participants exhibited a significant increase in relative left frontal activity following the anger induction, $t(35) = 7.48$, $p < .001$. Furthermore, to ensure that we did not bias the selected sample to show RewP differences across conditions, we conducted correlations between relative left frontal alpha activity and the RewP to revenge trial win feedback for both participants included for analysis and participants excluded for analysis. Both correlations were not significant, p's > .276.

[10] A 3 (trial type) x 2 (outcome) repeated-measure ANOVA examining the RewP that included all participants, including those who were originally excluded, did not reveal a significant interaction, $F(2, 104) = 0.66$, $p = .520$, $\eta_p^2 = .01$.

[11] Because the RewP can potentially have strong temporal overlap with the P3 (Holroyd et al., 2003; Novak & Foti, 2015), we, once again, examined the P3 to feedback. Similar to Experiment 1, the P3 was assessed at site CZ within a window of 350–600 ms after feedback onset. A 3 (trial type: revenge vs. bank vs. no-consequence) x 2 (outcome: win vs. loss) repeated-measures ANOVA for the P3 did not reveal a significant interaction, $F(2, 68) = 0.25$, $p = .779$, $\eta_p^2 = .007$.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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