

THE EFFECTS OF EXPECTANCY AND AUTONOMY  
ON NEURAL MEASURES OF MOTIVATION

by

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## ABSTRACT

Motivation drives humans to attain desired goals or objects by enhancing our attention, facilitating faster physical movement, and reinforcing behaviors that lead to goal acquisition. Behavioral and physiological studies find evidence for this effect by manipulating extrinsic motivation using pre-goal states and implementing rewards. Further research on motivation suggests intrinsic motivation also has similar behavioral effects to extrinsic motivation. The current studies examined whether performance expectancy and autonomy enhance motivation using behavioral and electroencephalography (EEG) measures. Study 1 manipulated performance expectations that a flanker task would be difficult or easy based on a social comparison. Study 2 manipulated autonomy by giving participants a choice of task and self-controlled feedback. Study 1 results revealed greater neural motor-action preparation and feedback processing to difficult (vs. easy) expectancy trials. Difficult expectancy also narrowed attention but did not reveal performance differences with RT. Participants also self-reported marginally greater high-approach motivation during difficult (vs. easy) expectancy. Study 2 results revealed no difference in neural motor-action preparation and feedback processing to autonomy (vs. no autonomy). Autonomy also broadened (rather than narrowed) attention. Autonomy also increased response times to a flanker task. Participants self-reported marginally more low-approach motivation during autonomy (vs. no autonomy). Taken together, results suggest not all forms of intrinsic motivation influence motivation in similar ways. Based on neural and behavioral measures, it seems performance expectancy enhances high motivational intensity, while autonomy enhances low motivational intensity.

## LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of Variance
EEG	Electroencephalography
dB	Decibel
ERP	Event-related brain potential
RewP	Reward positivity
$F$	Fisher's $F$ ration: a ratio of two variances
$n$	Sample Size
$M$	Mean: the sum of a set of measurements divided by the number of measurements in the set
$SD$	Standard deviation: measure of the variation of a set of data values from its mean
$p$	Probability associated with the occurrence of obtaining a value equal to or greater than the observed value under conditions of the null hypothesis
$\eta_p^2$	Partial eta squared effect size
$d$	Cohen's $d$ effect size

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## INTRODUCTION

Motivation is critical in dictating an individual's effort to accomplish or attain a goal. Motivation activates the intent or the physical movement towards (approach) or away (withdraw) from something (Harmon-Jones & Gable, 2017). These actions or intended actions are crucial for reproduction, relationships, resources for survival, obtaining rewards, and avoiding punishment (Gable & Harmon-Jones, 2010b). There are two main types of motivation: intrinsic and extrinsic (Ryan & Deci, 2000). Broadly, extrinsic motivation is the drive to act, or behave with the purpose of attaining or experiencing some external consequence (Deci, Olafsen, & Ryan, 2017). On the other hand, intrinsic motivation is primarily driven by interest or inherent satisfaction for some activity (Di Domenico, & Ryan, 2017). Much of the past literature examining the neural correlates and cognitive consequences of motivation have primarily focused on extrinsic motivators (e.g., money). The current studies seek to investigate whether intrinsic motivation activates similar effects on neural processes of motor-action preparation, feedback processing, and cognitive scope as extrinsic motivators.

Motivation has a direct impact on behaviors that help us acquire desired objects or goals. It does so by facilitating faster motor movements (Gable, Threadgill, & Adams, 2016). Enhanced motor performance is what often helps us acquire rewards and goals (Behan, Stone, & Garavan, 2015; Gable et al., 2016; Meadows, Gable, Lohse, & Miller, 2016a). Increasing motivation reinforces behaviors that lead to future goal acquisition because it enhances sensitivity to reward feedback (Meadows, Gable, Lohse, & Miller, 2016b; Sutton & Barto, 1998; Threadgill & Gable, 2016). Motivation also affects attentional scope by narrowing (focusing on



local elements of the visual field) instead of broadening (focusing on the entire picture as a whole) attention (Gable & Harmon-Jones, 2010a, 2011; Gable et al., 2016; Harmon-Jones & Gable, 2008; Hicks, Fields, Davis, & Gable, 2015; Knutson, Westdorp, Kaiser, & Hommer, 2000). This narrowing of attentional scope allows cognitive resources to be directed at attaining a goal or performing a specific action (Fredrickson & Brannigan, 2005; Gable & Harmon-Jones, 2008; Gable & Harmon-Jones, 2013; Harmon-Jones, Gable, & Price, 2013; Hart & Gable, 2013; Rowe, Hirsh, & Anderson, 2007). In sum, motivation focuses our attention, makes us act faster, and makes us more sensitive to feedback when we want to accomplish something.

### **Motivational Dimensional Model**

Motivation is often evoked during instances of either positive or negative emotion, such as desire during appetitive pictures (Harmon-Jones & Gable, 2008) or anger provoking pictures (Gable, Poole, & Harmon-Jones, 2015). The motivational dimensional model proposes that increases in motivational intensity, independent of affective valence can narrow attentional scope and activate goal-directed behavior prior to a goal (Gable & Harmon-Jones, 2010b).

Specifically, this work finds approach motivation (motivational intensity) is enhanced towards primary rewards (e.g., delicious desserts) and secondary rewards (e.g., money; Gable & Harmon-Jones, 2008; Gable & Harmon-Jones, 2010a, 2011; Hicks, Fields, Davis, & Gable, 2015).

Research on this model also notes that approach motivation in monetary reward paradigms is enhanced prior to a goal (pre-goal) but is later reduced as soon as the goal is obtained (post-goal) due to the acquisition of that external reward (Gable & Harmon-Jones, 2011; Gable et al., 2016b; Knutson et al., 2000; Threadgill & Gable, 2016). Much of the past literature examining neural indicators and cognitive consequences of motivation has primarily focused on extrinsic

motivators (e.g., money or appetitive stimuli; Gable & Harmon-Jones, 2008; Gable et al., 2016a, 2016b; Threadgill & Gable, 2016).

### **Intrinsic Motivation**

Some researchers propose a distinction between where motivators stem from. Broadly, extrinsic motivation is the impulse to act or behave in a specific way with the purpose of obtaining some type of external outcome or consequence (e.g., money and rewards; Deci, Olafsen, & Ryan, 2017). However, according to Self-Determination Theory (SDT), Ryan and Deci (2000) propose that in addition to extrinsic motivation, there is a human drive for inherent growth and self-motivation that makes up intrinsic motivation. This intrinsic motivation is primarily driven by interest or inherent satisfaction for some activity (Di Domenico & Ryan, 2017). Specifically, Deci et al. (2017) suggest that motivation is a spectrum ranging from motivation that is autonomous (e.g., self-control, volition) or controlled (e.g., reward-based, power dynamics). Although extrinsic and intrinsic motivation can certainly have both autonomous and controlled characteristics, autonomous activities are most often intrinsic. The distinction between intrinsic motivation and extrinsic motivation has been investigated in relationship to an individual's ability to maintain motivation, implying that intrinsic motivators typically contribute to more sustained motivation (Deci, Koestner, & Ryan, 1999; Deci, Koestner, & Ryan, 2001; Ryan & Deci, 2000).

Intrinsic motivation is typically enhanced when individuals can identify with the importance and value of the activity they are attempting to accomplish (Deci et al., 2017). Such states may promote growth, social development, and well-being (Ryan & Deci, 2000). Intrinsically motivated states may also enhance goal accomplishment, as intrinsically motivated activities or jobs lead to less physical burnout (Fernet, Gagne, & Austin, 2010) and less

emotional exhaustion (Richter, Blanchard, & Vallerand, 2002). Individuals also feel like they perform better when they are intrinsically motivated (Kuvaas, 2009). In contrast, extrinsic motivation is typically controlled by a consequence or reward.

### **Performance Expectancy.**

From a social perspective, expectancy refers to self-created notions of how we will perform in the future based on evaluating how others performed in the same situations. These evaluations of the performance of others often form perceptions of task difficulty that help create the expectations of how one will perform in similar circumstances (Inzlicht, Shenav, & Olivola, 2018). Research shows that expectancy based on these social comparisons can enhance task performance (Wulf, Chiviakowsky, & Lewthwaite, 2012). More specifically, these performance expectations result in more efficient motor learning by enabling the individual to learn unfamiliar motor movements faster (e.g., throwing with their non-dominant hand; Avila, Chiviakowsky, Wulf, & Lewthwaite, 2012). This is especially true when performance feedback shows that an individual is better than others, even if the positive feedback is false (Avila et al., 2012; Lewthwaite & Wulf, 2010).

One reason why performance expectancy may act as a motivator for action and enhanced performance is that it provides a way to evaluate one's own abilities to perform and further internalize the situation (Wulf & Lewthwaite, 2016). For individuals, these normative expectations are important and internalized because they are important to the self (Wulf, Lewthwaite, & Hooyman, 2013). When these evaluations provide individuals with positive information about their performance (in relation to others), they increase motivation to continue to perform and learn (Lewthwaite & Wulf, 2010). Because performance expectancies (based on

social comparisons) are internalized and could be tied to self-efficacy, they are more intrinsically oriented (Deci et al., 2017; Di Domenico & Ryan, 2017).

Something important to consider when forming performance expectancies is the level of perceived difficulty for a task or activity. Inzlicht et al. (2018) note that difficulty is related to effort, as greater difficulty typically demands more effort. They also mention the commonly overlooked notion that more effort can make success feel more valuable and satisfying. Some studies examining the neural effects of varying difficulties (such as multiplying instead of adding) also show positive feedback elicits greater reward-related neural activity when more effort is required (Ma, Meng, Wang, & Shen, 2014).

There is also evidence to suggest individuals pay more attention to feedback when more effort is exerted. Wang, Zheng, and Meng (2017) examined neural activity with electroencephalography (EEG) during feedback to conditions varying in effort. Their results revealed that under conditions of higher effort (multiplying vs. adding) there was more interest in one's task performance and greater neural activity during the feedback processing phase of their task. This further highlights the need to examine neural feedback processing under varying expectations of task difficulty, primarily because paradigms that typically enhance neural activity during feedback have used external motivators as their motivation manipulators (Meadows et al., 2016b; Threadgill & Gable, 2016).

Scientists theorize that positive performance expectancy enhances intrinsically driven behavior (Avila et al., 2012; Chiviawosky et al., 2008; Janelle et al., 1997; Lewthwaite & Wulf, 2010; Patterson & Lee, 2010). However, these studies often assume motivation is enhanced, primarily by examining behavioral responses to a specific task (e.g., response times). More research needs to be done on whether intrinsically-based motivators modulate neural measures of

motivation, as is the case with extrinsic motivators. More studies that use neurological approaches to examine these effects are especially necessary because they may be able to narrow down how similar intrinsically-based motivators are based on neural network activity (Di Domenico & Ryan, 2017).

### **Autonomy.**

Autonomy also seems to enhance motivation, and therefore performance. Autonomy refers to an individual's perception of having some form of control over the environment. This sense of control is thought of as a psychological need because it makes us feel like an environment or situation is part of our own doing (Deci & Ryan, 2008). As a result, autonomy can enhance motivation, establish a sense of satisfaction, and improve an individual's sense of competence. Autonomy can also lead to physiological and subjective well-being by increasing energy (Deci & Ryan, 2000). Research shows that subjective well-being based on happiness/enjoyment is heavily influenced by perceived autonomy during various contexts. Greater autonomy to assessments in academic settings are related to greater perceived happiness, enjoyment, and well-being (Black & Deci, 2000; O'Donnell, Chang, & Miller, 2013). More autonomy from individuals' social support systems is also associated with happiness (Demir, Özdemir, & Marum, 2011).

Various degrees of autonomy can directly enhance motivation (Eitam, Kennedy, & Higgins, 2013). When given a choice in various tasks, like choosing to have indicators of good performance (feedback) or being able to choose the type of rewards, individuals show enhanced motivation and perform better, regardless of how much effort must be exerted (Eitam et al., 2013; Tiger, Hanley, & Hernandez, 2006). When individuals are given the option to control whether or not they want to be told how they performed in various tasks (like physical and

computerized lab tasks), they were more motivated to perform well because, to some extent, the task became a part of their own doing (Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997).

This autonomy manipulation also appears to enhance motor learning, like learning how to throw with one's non-dominant hand and throwing a beanbag at a target with more accuracy (Chiviakowsky, Wulf, Laroque de Medeiros, Kaefer, & Tani, 2008; Janelle et al., 1997; Patterson & Lee, 2010; Wulf, Chiviakowsky, & Cardozo, 2014; Wulf, Chiviakowsky, & Drews, 2015).

Having greater autonomy over situations may meet a biological need. Leotti, Iyengar, and Ochsner (2010) argue that while resources (i.e., food and water) allow an individual to survive, being able to control some aspects of one's environment allows that individual to thrive. Therefore, people tend to seek opportunities that allow them to control their environment. Leotti and Delgado (2011) found that brain regions associated with reward processing, such as the ventral striatum (VS) and midbrain structures, were more active when anticipating the potential choice of response keys during a task, even when the potential rewards were the same in the no-choice condition. In sum, autonomy enhances motivation, performance, learning, and well-being. It seems likely that autonomy will influence cognitive scope and action preparation during goal pursuit. The current studies sought to examine the motivational intensity of manipulations of autonomy and performance expectancy by assessing their influence on neurophysiological markers of motor-action preparation and feedback processing; two widely used measures of motivation (Gable et al., 2016b; Meadows et al., 2016a; Threadgill & Gable, 2016; Foti et al., 2015).

### **Beta Suppression**

Because motivation is crucial for stimulating action towards attaining or accomplishing goals, activity in motor and pre-motor areas of cortex are crucial (Babiloni et al., 2015;

Cunnington, Windischberger, Deeke, & Moser, 2002; Sanes & Donoghue, 1993). Motor and pre-motor areas of the cortex become more active during movement-related actions even when an individual merely thinks about or imagines movement (McFarland, Miner, Vauhan, & Wolpaw, 2000). This increased activation suppresses beta and alpha wave activity over these regions (McFarland et al., 2000; Pfurtscheller, Brunner, Schlögl, & Lopes da Silva, 2006). The beta band activity (13-30 Hz) measured by electroencephalography (EEG) is frequently used for examining suppression that relates primarily to motor-action preparation before an incentivized stimulus (Doyle, Darrow, & Brown, 2005; Gable et al., 2016b; Meadows et al., 2016a).

Motivation can change cortical beta activity by increasing dopamine levels (Tobler, Fiorillo, & Schultz, 2005). Higher dopamine levels suppress cortical beta activity (Jenkinson & Brown, 2011; Kühn et al., 2008). Therefore, situations that involve extrinsic rewards like money, suppress beta activity relative to states in which no monetary gain can be achieved (Gable et al., 2016). Meyniel and Pessiglione (2014) used various levels of monetary incentives to motivate their participants. They found beta suppression was greater when reward magnitude was increased. The suppression of beta activity that occurs with more motivated states also leads to enhanced preparation for actions, manifested by faster reaction times (Doyle et al., 2005; Gable, et al., 2016b; van Wijk, Daffertshorster, Roach, & Praamstra, 2009).

In sum, various manipulations of extrinsically motivating states appear to enhance motor action preparation. However, it could be possible that extrinsic motivators only influence beta suppression because they have exogenous objects or goals to move towards. The current studies examined whether autonomy and performance expectancy (intrinsic motivators) without exogenous rewards would also enhance beta suppression.

## **Reward Positivity**

Recent work has shown that motivation also impacts neural feedback processing. The Reward Positivity (RewP) is an event-related potential (ERP) component that accurately reflects appraisal of performance feedback monitoring after extrinsically motivating states (Meadows et al., 2016b; Proudfit, 2015; Threadgill & Gable, 2016). This component consists of a positive deflection in the ERP wave that occurs roughly between 200-350ms after feedback onset most often at frontocentral sites.

RewP wave amplitudes are significantly larger when an individual is given positive feedback of monetary gains, instead of negative or neutral feedback (Holroyd, Hajcak, & Larsen, 2006; Holroyd, Krigolson, & Lee, 2011; Weinberg, Riesel, & Proudfit, 2014). Frömer, Stürmer, and Sommer (2016) had varying graded feedback throughout a throwing task. They found RewP amplitudes were greater as accuracy got better throughout their task. Meadows et al. (2016b) also found comparable results with RewP amplitudes and incentive levels, where greater incentives elicited greater RewP waves. Larger RewP amplitudes are also related to greater trait approach-motivation (Lange, Leue, & Beauducel, 2012), as well as other approach-motivated traits like reward responsiveness, liking of desirable rewards, and perceived agency in acquiring rewards (Angus, Kemkes, Schutter, & HarmonJones, 2015; Bress & Hajcak, 2013; Yeung, Holroyd, & Cohen, 2005). Broadly, this literature suggests that extrinsic motivation enhances feedback-processing as seen by the RewP, and that RewP amplitudes may be particularly sensitive to extrinsic reward magnitudes.

Research shows the RewP is related to dopamine release in neural reward-processing regions, such as the basal ganglia and anterior cingulate cortex (Foti, Weinberg, Dien, & Hajcak, 2011; Foti, Weinberg, Bernat, & Proudfit, 2015; Hauser et al., 2014). The increase in dopamine



reflected by the RewP aids in reinforcing behaviors that can lead to the acquisition of monetary rewards or accomplishing goals in the future (Holroyd & Coles, 2002; Holroyd & Yeung, 2012). This increase in dopamine activity is shown to be enhanced by greater motivation (Tobler et al., 2005).

Prior research shows RewP amplitudes may be especially sensitive to the magnitude of extrinsic motivators (Meadows et al., 2016b). This could potentially mean that RewP amplitudes, and the neural feedback processing these reflect, could be specifically tied to the monitoring the magnitude of extrinsic motivators, rather than motivational consequences for feedback processing. The present studies investigated whether autonomy and performance expectancy (intrinsic motivators) increased RewP amplitudes during feedback, specifically positive feedback.

### **Attentional Scope**

Motivation facilitates a more narrowed attentional scope. Prior studies have shown that extrinsically motivated states facilitate faster responses to local elements on Navon's (1977) letter task after viewing pictures and films of appetitive desserts (Gable & Harmon-Jones, 2008), viewing pictures of alcoholic beverages (Gable, Mechin, & Neal, 2016), and having the potential to receive monetary rewards (Gable & Harmon-Jones, 2010a, 2011). This narrowing of attention is effectively measured by using tasks such as the Navon (1977) letter's task. This task consists of big letters (global elements) made up of smaller letters (local elements). Identifying the local elements faster indicates a narrowed attentional scope.

Other studies have shown similar attentional effects to motivated states (e.g., monetary gains) with memory of centrally (locally) vs. peripherally (globally) presented words (Gable, & Harmon-Jones, 2010a; Gable et al., 2016a, 2016b). In sum, a narrowed attentional scope allows

us to focus our cognitive and attentional resources on obtaining a goal or object. Research shows these attentional changes are direct consequences of enhanced extrinsic motivational states (Gable & Harmon-Jones, 2011). The present studies also examined whether autonomy and performance expectancy can also narrow attentional scope due to an enhanced motivational state.

### **The Current Studies**

Previous work shows that manipulating feelings of autonomy and creating performance expectancy based on social comparisons enhance the motivation necessary for better performance and motor-actions (Wulf & Lewthwaite, 2016). Theoretical and behavioral research suggest that autonomy and performance expectancy increase motivation (Avila et al., 2012; Chiviawosky et al., 2008; Janelle et al., 1997; Lewthwaite & Wulf, 2010; Patterson & Lee, 2010). However, prior work with intrinsic motivation has not investigated the motivational intensity caused by autonomy and performance expectancy. Specifically, reliable neural and cognitive scope measures are necessary to determine the motivational intensity of these intrinsic motivators. Autonomy and performance expectancy are predicted to suppress cortical beta activity, increase RewP amplitudes during positive feedback processing, and narrow attentional scope. The current thesis examined this across two studies.

Study 1 manipulated performance expectancy by creating the expectancy that a task would be difficult or easy based on a social comparison. Participants received manipulated feedback during difficult and easy trials to allow them to feel like they were performing better than the social comparison during difficult trials and worse than the social comparison during easy trials. Study 2 manipulated autonomy by granting participants the opportunity to choose tasks and have self-controlled feedback.

If difficult expectancy and autonomy cause high motivational intensity, there should be greater beta suppression during instances where a task is expected to be difficult (vs. easy) and the individual has more autonomy (vs. no autonomy). RewP amplitudes should also be greater during winning feedback in those conditions to reflect enhanced neural feedback processing. Greater attentional narrowing should also occur due to enhanced motivation, as reflected by faster RTs to local target stimuli. There should also be faster RTs to a simple behavioral task during a difficult expectancy condition (vs. easy) and during an autonomy tasks (vs. no autonomy). If difficult expectancy and autonomy cause low motivational intensity, there should be no differences in beta suppression, RewP amplitudes during winning feedback, greater attentional broadening, and RTs should be slower to simple behavioral tasks.

## STUDY 1 METHODS

### Participants

Forty undergraduate students from the University of Alabama online PY-101 subject pool participated for partial course credit throughout the course of one semester. This sample size met the initial power analysis using the G\*Power computer program (Faul, Erdfiler, Lang, & Buchner, 2007), based on moderate effect size ( $f = .25$ ) expectations (under guidelines from Cohen, 1988), that indicated a total sample size of 36 would be needed to detect moderate effects with .80 power using repeated measures ANOVA with alpha set at .05.

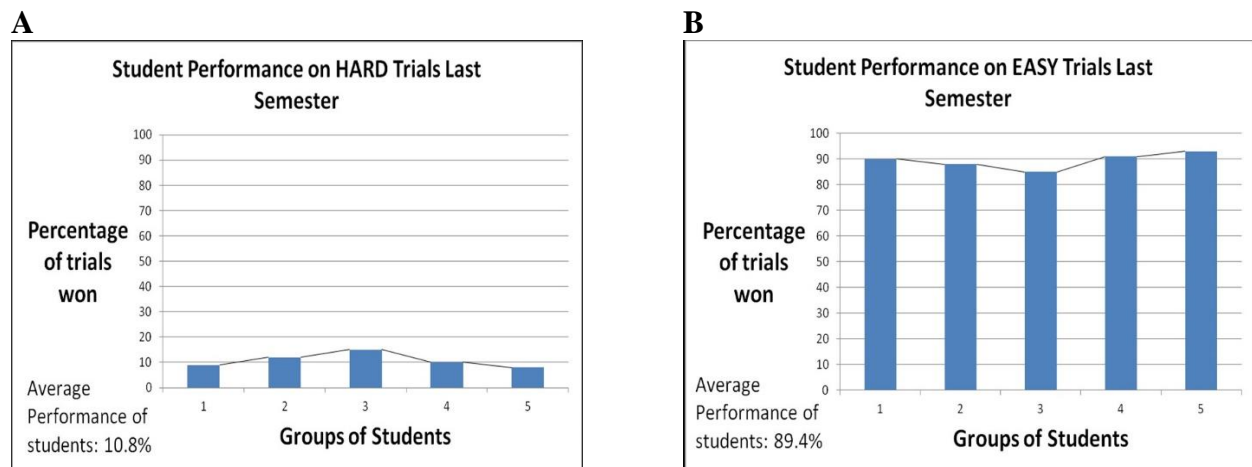
### Procedure

Following informed consent, participants were asked to complete measures of handedness by using a 13-item list asking about which hand they use to perform various day-to-day tasks (Gable & Poole, 2014; Neal & Gable, 2017). These included things like: drawing, writing, using scissors, etc. A participant was classified as right handed if they performed no more than one of the items on the list with their left hand. Participants who are left handed were not included in the sample. This was followed by demographic information like sex, age, and ethnicity.

After applying the EEG stretch lycra cap to their scalp, participants were asked to play a reaction time game that would vary in difficulty level throughout. To win the reaction time game, participants had to respond quickly to a flanker's task (Eriksen & Eriksen, 1974). Trials ( $n = 96$ ) were broken up into 8 blocks of 12 trials each. Four of these blocks generated the

expectancy of being difficult trials to beat and the other 4 blocks generated the expectancy of being easy trials to beat. Blocks were presented in pseudorandomized order.

To create the expectancy that trials would be easy or difficult, expectancies were formed based on a social comparison by ostensibly showing past performance of others on each task (Ávila et al., 2012; Lewthwaite & Wulf, 2010; Wulf et al., 2013). Participants saw a bar graph depicting false performance of five groups of students. The average performance of the groups shown in the graphs depended on whether the block was an easy or difficult block of trials. Difficult blocks demonstrated approximately a 10% success rate. Easy blocks demonstrated approximately a 90% success rate (see Figures 1A and 1B for sample graphs). Participants were told they needed to be both accurate and fast enough to successfully win each trial. After the graph, participants were asked to state the percentage of trials they expected to get correct on that block. Participants then completed the block of trials.



**Figure 1.** (A) Graph shown to participants prior to a block of difficult trials. (B) Graph shown to participants prior to a block of easy trials.

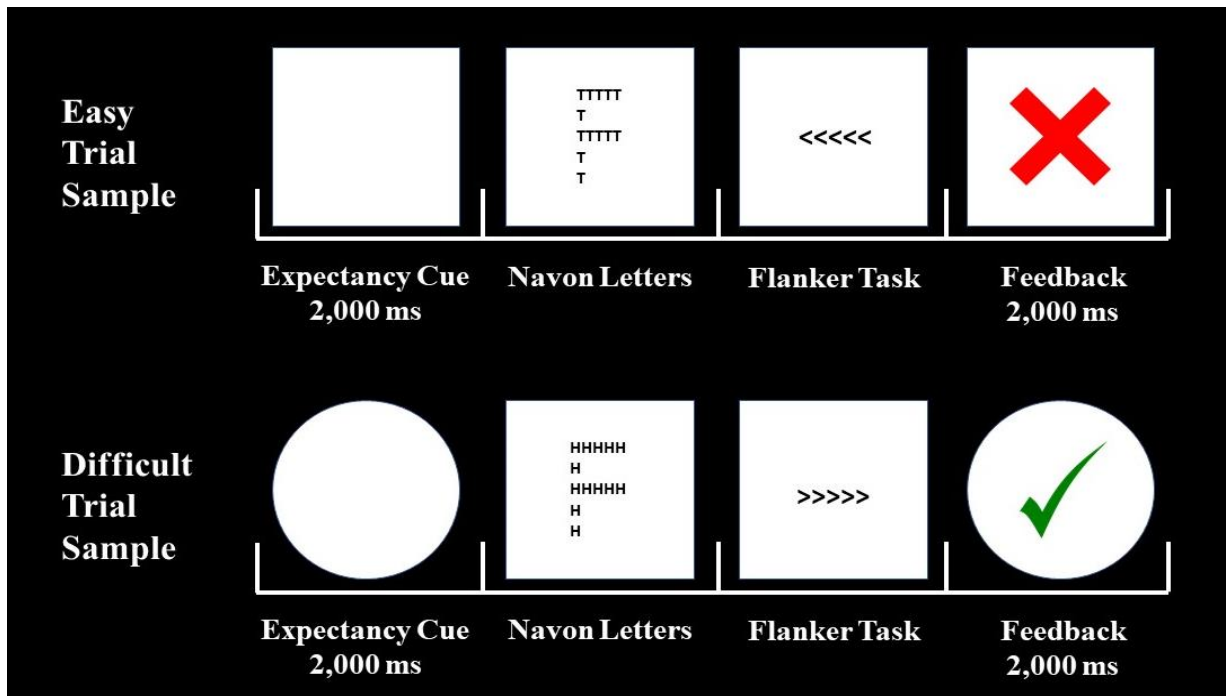
Each trial began with a cue presented at the center of the screen for 2,000 ms. White circles represented trials that were expected to be difficult to beat (i.e., trials where others

performed poorly). In contrast, white squares represented trials that were expected to be easy to beat (i.e., trials where others performed well).

After each cue, a Navon (1977) letter was presented at the center of the computer screen to measure attentional scope. These Navon letters consist of identifying local and global elements (T's or H's) that make up the letter stimuli. Local elements are the small letters that make up a larger letter (e.g., an F made up of small H's). Global elements are the large letters that are made up of smaller letters (e.g., a T made up of small F's). There was an equal number of letters containing global and local elements per block. Faster response times when identifying local elements are indicative of narrowed attentional scope, while faster responses to the global elements reflect a more broadened attentional scope. This measure of attentional scope has been used in various motivation studies (Gable & Harmon-Jones, 2008; Gable et al., 2016b; Hicks, Friedman, Gable, & Davis, 2012; Hicks, Fields, David, & Gable, 2015). Participants were told their responses to these letters would not determine whether they won a trial, but they were still asked to respond to them as quickly as possible. Responses were made by pressing the left and right shift keys on a keyboard.

Next, participants responded to a flanker (Eriksen & Eriksen, 1974) as part of the main goal-related task. For each flanker, participants had to quickly identify the direction of the center arrow among a series of five arrows. The center arrows were either congruent (pointing in the same direction) or incongruent (pointing in the opposite direction) to the other arrows. Each block had an equal number of congruent and incongruent flankers. Past work has found greater motivation - in the form of extrinsic monetary rewards - speeds reaction times on this task (Gable et al., 2016; Threadgill & Gable, 2016). Responses to flankers were made by pressing the left and right shift keys on a keyboard.

Following their responses to each flanker, feedback on whether they won or lost the trial was shown for 2,000 ms. Feedback consisted of a green “checkmark” if they won the trial or a red “X” if they lost the trial. These were displayed inside the same shape as the initial cue for that trial. Difficult trials had feedback over white circles and easy trials had feedback over white squares. Feedback was manipulated so that participants won approximately 50% of trials in both conditions (see Figure 2 for a sample trial sequence).



**Figure 2.** Sample trials. There was a variable ISI between 500-700 ms after each initial cue, Navon letter, and flanker for each trial.

For manipulation checks, participants reported their perceived success rate on a scale ranging from 1 (10%-20%) to 9 (91% - 100%). They also rated how well they thought they did in relation to others depicted in the graphs on a scale ranging from 1 (*Much Worse*) to 7 (*Much Better*). Finally, they rated how much effort they put into the task in relation to others on a scale ranging from 1 (*A lot less effort*) to 7 (*A lot more effort*).

Finally, participants were shown sample pictures of the cues and feedback that appeared throughout the task. For each picture, participants were asked how they felt (*sad, glad, nervous,*

*enthusiastic, happy, excited, angry, down, mad, and anxious*) using a scale ranging from 0 (*no emotion*) to 7 (*strongest feeling*; Gable & Harmon-Jones, 2008).

Beta suppression was analyzed during cues that indicated the type of trials: Difficult vs. easy trials. The RewP ERP amplitudes were analyzed during feedback: Difficult vs. easy trial wins and losses. Finally, Navon letter and flanker RTs were analyzed as the attentional and performance measures (respectively).

The study was completed at a computer using Inquisit Lab stimulus presentation software (Inquisit 4.0.10, 2015). Response times (RTs) for the Navon letters task and flanker task were logarithmically transformed. Trials with incorrect responses for the Navon letters and flankers (< 8% and < 9% respectively) and trials for which RTs, beta suppression, and RewP amplitudes were more than 3 standard deviations from the mean ( $\leq 7.5$  % of the sample) were excluded from analyses (Fazio, 1990; Gable & Harmon-Jones, 2008; Threadgill & Gable, 2016).

### **Electroencephalography (EEG) Assessment**

Electroencephalography (EEG) activity was recorded using 59 tin electrodes in a stretch-lycra cap (Electro-Cap, Eaton, OH). The ground sensor was placed midway between FZ and FPZ. Recorded data was referenced to the left earlobe. Electrode impedances were kept under 5 k $\Omega$  (with homologous sites within 1 k $\Omega$  of one another). Recordings were amplified with NeuroScan SynAmps RT amplifier units (El Paso, TX). These were low pass filtered at 100 Hz, high-pass filtered at 0.05 Hz, notch filtered at 60 Hz, and digitized at 500 Hz. A filter slope was set at 12 dB per octave. Initially, data were hand inspected for artifacts, then transformed with a regression-based eye blink correction. Data were then visually inspected a second time to ensure proper correction.



The duration of all epochs for beta frequency analyses was 1,024ms. These were extracted using a Hamming window, where consecutive epochs overlapped by 50%. Data were referenced offline using an average ears reference. Power spectra were calculated using a fast Fourier transform and power values for beta band (13-30 Hz) were averaged across all epochs and regions of the head at sites over the motor cortex: C1, C2, C3, C4, C5, C6, CP1, CP2, CP3, CP4, CP5, and CP6 (Gable et al., 2016; McFarland et al., 2000; Muthukumaraswamy, Johnson, & McNair, 2004; Pfurtscheller, Neuper, Brunner, & da Silva, 2005; R  ther, Brown, Klepp, & Bellebaum, 2014).

Consistent with past work analyzing the RewP, data were epoched 100ms prior to feedback onset until 1,200ms after feedback onset and low-pass filtered at 35 Hz (Threadgill & Gable, 2016). Mean waveforms for each feedback type were created and baseline corrected based on the pre-stimulus activity (100ms). Trials with errors were excluded from ERP analyses. The RewP mean amplitudes were assessed where the values were maximal at site PZ with a window of 220-300ms after feedback onset (Baker & Holroyd, 2011; Foti et al., 2011; Foti, Kotov, Bromet, & Hajcak, 2012; Gable et al., 2016; Meadows et al., 2016b; Proudfit, 2015; Weinberg et al., 2014; Williams, Hassall, Trska, Holroyd, & Krigolson, 2017).

## STUDY 1 RESULTS

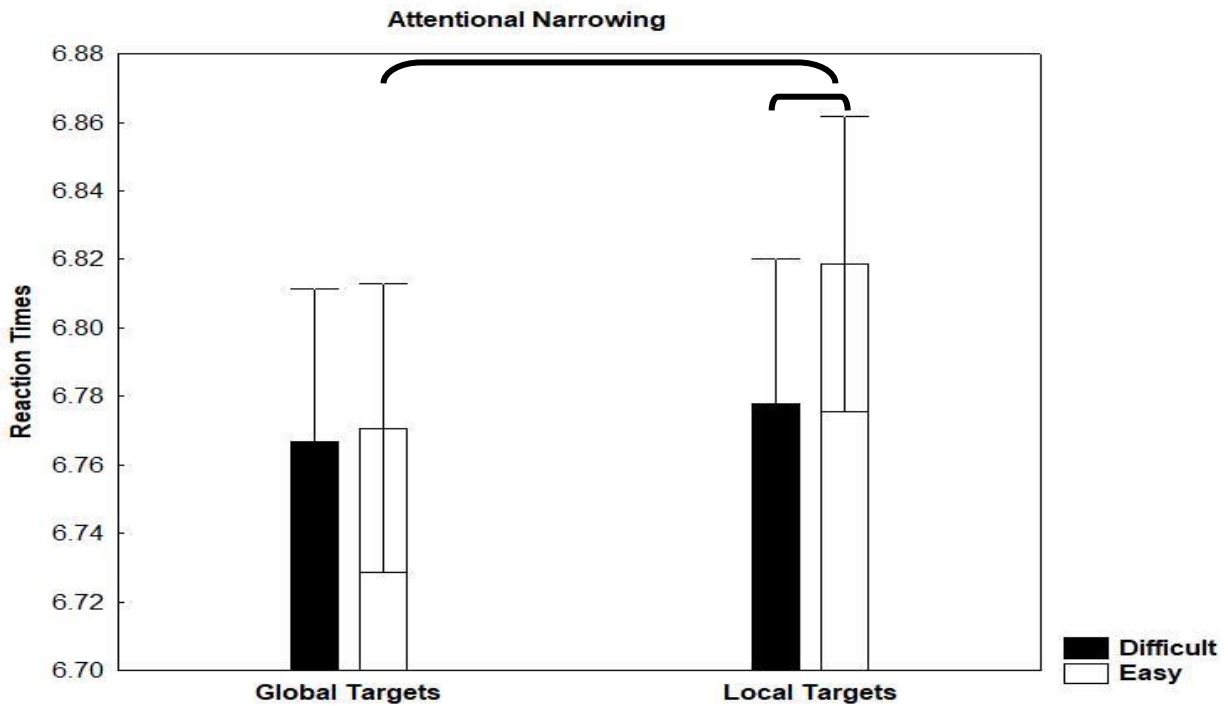
### Manipulation Checks

A dependent samples *t*-test revealed that participants expected to do worse in the difficult blocks ( $M = 2.72, SD = 1.77$ ) than easy blocks ( $M = 6.32, SD = 1.53$ ),  $t(39) = -11.72, p < .000001, d = 2.18$ . This means participants expected the difficult trials would be more difficult than the easy trials. Participants felt they had performed more poorly after finishing the difficult blocks ( $M = 3.29, SD = 1.63$ ) than the easy blocks ( $M = 4.62, SD = 1.65$ ),  $t(39) = -5.94, p < .00001, d = 0.81$ . Participants believed the difficult blocks were still more difficult than the easy trials, even after completing the block with manipulated success rate of about 50%. They also believed they had performed about the same as the students depicted in the graph during the difficult blocks ( $M = 3.98, SD = 1.22$ ), but worse than the students depicted in the easy blocks ( $M = 2.92, SD = 1.15$ ),  $t(39) = 4.93, p < .0001, d = 0.89$ . These manipulation checks suggest the manipulation produced the desired expectancy of difficulty level in participants throughout the experiment. Participants did not report feeling like they put more effort into the task than the people depicted in the graph ( $p > .57$ ).

### Attentional Narrowing

A 2 (Difficult vs. Easy) X 2 (Global vs. Local) repeated measures ANOVA revealed a significant interaction,  $F(1, 38) = 5.27, p < .03, \eta_p^2 = .12$  (see Figure 3). Post-hoc analyses revealed RTs were faster to local targets in the difficult ( $M = 6.78, SD = .27$ ) than in the easy ( $M = 6.82, SD = .27$ ) condition ( $p < .006, d = .15$ ) and faster to global ( $M = 6.77, SD = .26$ ) than local ( $M = 6.82, SD = .27$ ) targets in the easy condition ( $p < .001, d = .18$ ). There were no

differences between global and local RTs in the difficult condition and global RTs between the difficult and easy conditions ( $p_s > .99$ ). These results suggest there was greater attentional narrowing in the difficult trials than in the easy trials, primarily reflected by the faster RTs to the local targets in the difficult trials.



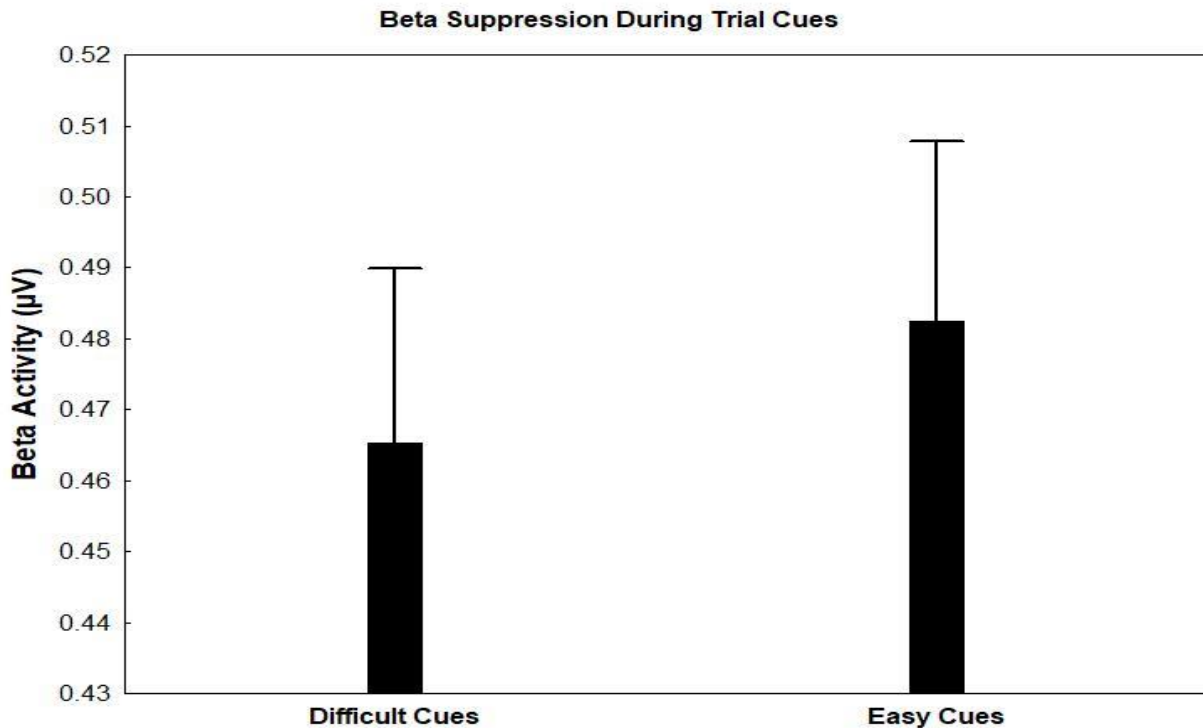
**Figure 3.** Attentional narrowing reflected by Navon letter reaction times. Brackets indicate significant differences between conditions. Error bars represent standard errors from the mean.

### Flankers

A repeated measures ANOVA revealed no significant difference in reaction times between the difficult and easy conditions,  $F(1, 36) = 0.35, p > .55$ . This may have been the case because flanker response demands are simple (as reflected by high success rates) even under no motivational drives (Huizinga, Dolan, Van der Molen, 2006). There was also no further demand (other than the instructions) that would add the time pressure that often reduces response times (Dambacher & Hübner, 2015).

## Beta Suppression

A repeated measures analysis of variance (ANOVA) revealed beta suppression was greater during the difficult cues than easy cues,  $F(1, 36) = 4.24, p < .05, \eta_p^2 = .11$  (see Figure 4). This suggests there was greater motor-action preparation during the difficult cues ( $M = 0.46, SD = 0.15$ ) than during easy cues ( $M = 0.48, SD = 0.15$ ).

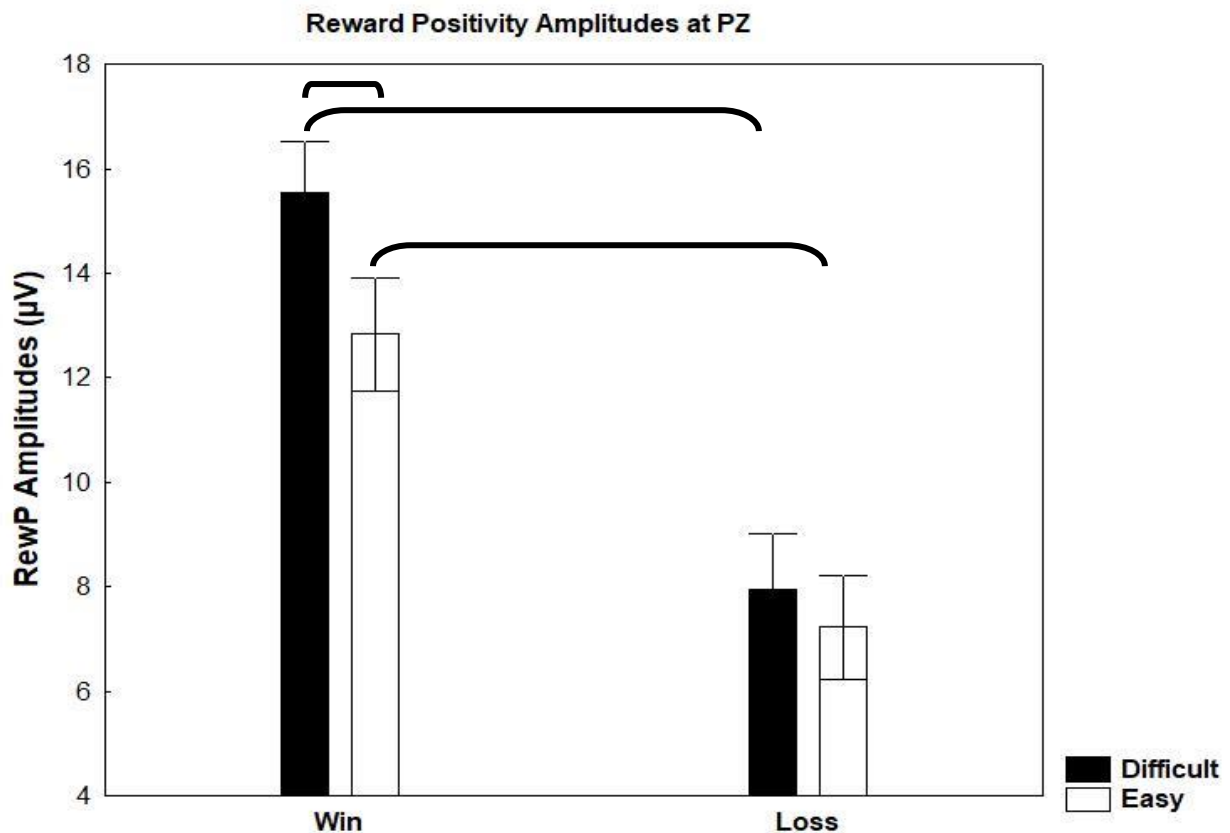


**Figure 4.** Beta activity over the motor cortex. Lower scores indicate greater beta suppression and motor-action preparation. Error bars represent the standard errors from the mean.

## Reward Positivity

For site PZ, a 2 (Difficult vs. Easy) X 2 (Win vs. Loss) repeated measures ANOVA revealed a significant main effect for the difficult vs. easy condition,  $F(1, 38) = 9.21, p < .005, \eta_p^2 = .20$ , and a significant main effect for win vs. loss feedback,  $F(1, 38) = 79.92, p < .000001$ . There was also a trending interaction,  $F(1, 38) = 3.81, p = .058, \eta_p^2 = .09$  (see Figure 5). Post-hoc analyses revealed RewP amplitudes were significantly greater during difficult wins ( $M = 15.53, SD = 6.23$ ) vs. easy ( $M = 12.83, SD = 6.74$ ) wins ( $p < .004, d = .42$ ). RewP amplitudes

were greater for difficult wins ( $M = 15.53$ ,  $SD = 6.23$ ) vs. difficult losses ( $M = 7.94$ ,  $SD = 6.78$ ;  $p < .000001$ ,  $d = 1.17$ ). RewP amplitudes were also greater for easy wins ( $M = 12.83$ ,  $SD = 6.74$ ) vs. easy losses ( $M = 7.23$ ,  $SD = 6.21$ ;  $p < .000001$ ,  $d = .86$ ). There was no difference between difficult losses and easy losses ( $p > .90$ ).



**Figure 5.** Reward Positivity amplitudes for site PZ. Brackets indicate significant differences between conditions. Error bars represent standard errors from the mean.

### Emotion Ratings

Exploratory analyses, in light of the current results, were conducted with the emotion ratings to the stimuli of interest (initial trial cues and win stimuli in the difficult and easy conditions) for this study. Participants indicated their emotions (*sad, glad, nervous, enthusiastic, happy, excited, angry, down, mad, and anxious*) to these stimuli. Positive emotions low in

approach motivation (*glad* and *happy*) were averaged and compared to positive emotions high in approach motivation (*enthusiastic* and *excited*) for autonomy and no autonomy conditions. A 2 (Difficult vs. Easy) X 2 (Positive Affect: High vs. Low) repeated measures ANOVA for participant self-reported emotions during trial cues revealed a marginal interaction,  $F(1, 35) = 2.25, p < .15, \eta_p^2 = .06$ . Post-hoc analyses revealed that participants reported feeling greater positive high-approach affect in the difficult ( $M = 2.21, SD = 1.43$ ) than in the easy condition ( $M = 1.87, SD = 1.32; p < .006, d = .25$ ). All other comparisons did not show any marginal or significant differences ( $ps > .22$ ).

A 2 (Difficult vs. Easy) X 2 (Positive Affect: High vs. Low) repeated measures ANOVA for participant self-reported emotions during winning feedback revealed a marginal main effect for difficult vs. easy,  $F(1, 35) = 3.92, p < .06, \eta_p^2 = .10$ , where participants reported greater positive affect of both types for the difficult condition ( $M = 4.52, SD = 1.83$ ) than for the easy condition ( $M = 3.98, SD = 1.93$ ). There was also a significant main effect for low vs. high approach positive affect,  $F(1, 35) = 5.92, p < .03, \eta_p^2 = .14$ , where participants reported greater positive low-approach ( $M = 4.40, SD = 1.65$ ) than positive high-approach affect ( $M = 4.10, SD = 1.82$ ). There was no interaction. However, further follow-up analyses showed low-approach positive affect was greater in the difficult ( $M = 4.66, SD = 1.78$ ) than in the easy condition ( $M = 4.13, SD = 1.92; p < .0001, d = .29$ ). Taken together, the emotional rating results for the initial trial cues and winning feedback seem to suggest the positive affect experienced during trial cues (pre-goal) may have been higher in approach-motivation for difficult trials than easy trials. However, low-approach positive affect was for both conditions during feedback. This is similar to what would be expected from a pre- and post-goal paradigm with extrinsic rewards.

## STUDY 2 METHODS

### Participants

A total of forty-five undergraduate students from the University of Alabama online PY-101 subject pool participated for partial course credit throughout the course of one semester. This sample size met the initial power analysis using the G\*Power computer program (Faul, et al., 2007), based on moderate effect size ( $f = .25$ ) expectations (under guidelines from Cohen, 1988), that indicated a total sample size of 34 would be needed to detect moderate effects with .80 power using repeated measures ANOVA with alpha set at .05.

### Procedure

Like in Study 1, participants were asked to complete measures of handedness and demographic information. All participants were right handed. The EEG stretch lycra cap was then applied to their scalp. Participants were asked to play reaction time games similar to the game in Study 1. Trials ( $n = 120$ ) were broken up into 2 different games, with 3 blocks of 20 trials in each game. For one of the games participants were given a choice (autonomy) over which task they could do and whether to receive feedback on how well they did after every trial. In the other game, participants were told the experimenter picked the game for them and they would not have a choice of whether they would receive feedback (no autonomy).

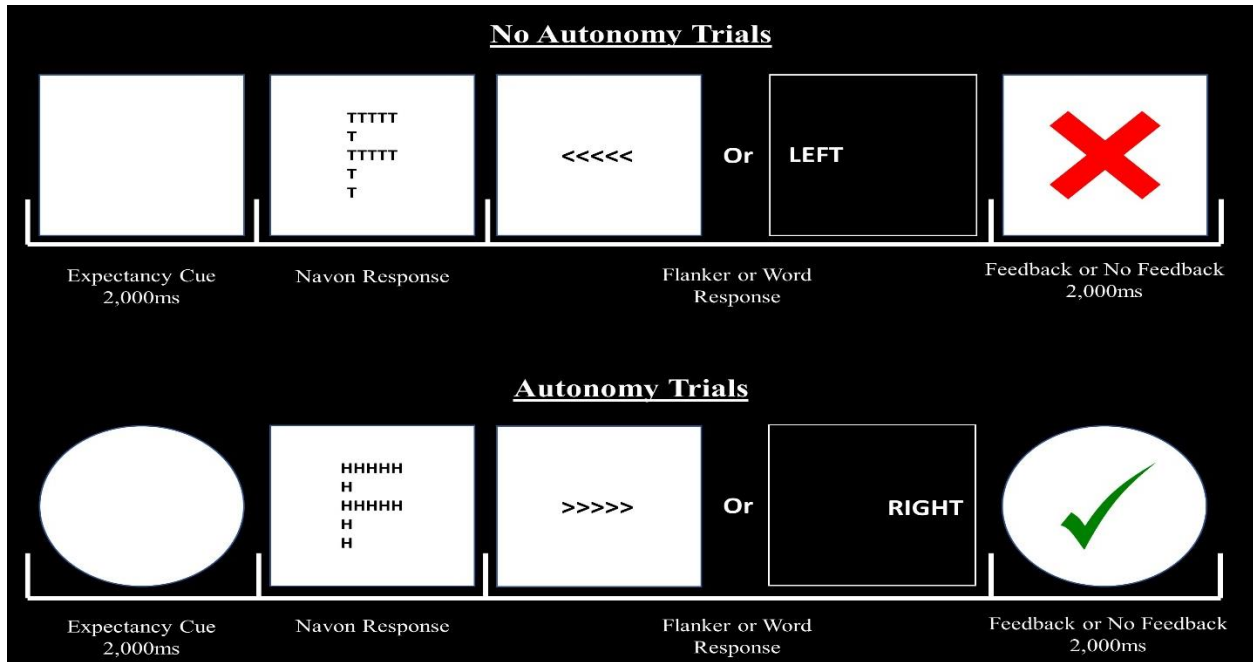
For the autonomy game, participants were given a list of four games (and brief descriptions) they could choose from (Legault & Inzlicht, 2013). The list of games was as follows: 1) The Mental Distraction Game, 2) A Game of Reactions, 3) Ignore Your Impulses, and 4) Cognitive Response Test. The same game would be played regardless of what choice

they made, unbeknownst to the participants. For the no autonomy game, participants were shown the same list but were told the experimenter had chosen a game for them.

One of the games played was the same as the flanker task from Study 1. The other game was similar. However, instead of using arrow flankers, it used words on the screen that said “RIGHT” or “LEFT.” Participants had to select the correct shift key based on what the word said. To have congruent and incongruent responses like in the arrows flanker task, sometimes the words appeared on the correct side of the screen (e.g., “RIGHT” appearing on the right side of the screen) and sometimes they appeared on the other opposite side of the screen (e.g., “LEFT” appearing on the right side of the screen). Participants were told they needed to respond based on the word and not the placement of the word. It was necessary to have participants complete different games to create the perceived task choice for one of them. However, these two games were expected to be similar and analyzed together.

The autonomy and no autonomy games were counterbalanced across these two games so that participants would not have to play the same game twice. The order in which autonomy and no autonomy games were played was also counterbalanced. In both games, participants were still asked to respond to Navon letters before the flanker (or word) appeared on the screen for each trial. Initial trial cues were also included in both games to indicate the autonomy and no autonomy trials. Just like in Study 1, feedback was manipulated to have approximately a 50% success rate (see Figure 6 for sample trials). To ensure equal number of trials with and without feedback throughout the two tasks, the blocks of trials with feedback in the no autonomy task were yoked to the blocks of trials where feedback was chosen in the autonomy task.





**Figure 6.** Sample trials. There was a variable ISI between 500-700ms after the initial cue, Navon letter, and flanker for each trial.

After each game, participants were asked to report how much choice they had over the task on a scale ranging from 1 (*It was entirely out of my hands*) to 7 (*It was entirely up to me*). They then responded to the same scale about how much choice they had over receiving feedback. They also reported how much effort they put into the task on a scale ranging from 1 (*No effort at all*) to 7 (*A lot of effort*). Finally, they reported how much enjoyment they felt during the task on a scale ranging from 1 (*None at all*) to 7 (*A whole lot*).

Finally, participants completed the same self-reported emotional check that was used at the end of Study 1. However, they reported the emotions to stimuli from this study. EEG assessment and processing procedures were the same as in Study 1. Because the games participants were asked to play were similar in nature (all two-way and three-way interactions involving the task type: arrows flanker vs. words flanker were non-significant where  $ps > .10$ ), we collapsed across tasks to obtain the conditions of interest for this study (autonomy vs. no autonomy).

Like in Study 1, beta suppression was analyzed during cues that indicated the type of trials: Autonomy vs. no autonomy. The RewP ERP amplitudes were analyzed during feedback: Autonomy vs. no autonomy wins and losses. Finally, Navon letter and flanker RTs were analyzed as the attentional and performance measures, respectively.

The study was completed at a computer using Inquisit Lab stimulus presentation software (Inquisit 4.0.10, 2015). Response times (RTs) for the Navon letters task and flanker task were logarithmically transformed. Trials with incorrect responses for the Navon letters and flankers (< 20% and < 15% respectively) and trials for which RTs, beta suppression, and RewP amplitudes were more than 3 standard deviations from the mean ( $\leq 14\%$  of the sample) were excluded from analyses (Fazio, 1990; Gable & Harmon-Jones, 2008; Threadgill & Gable, 2016).

## STUDY 2 RESULTS

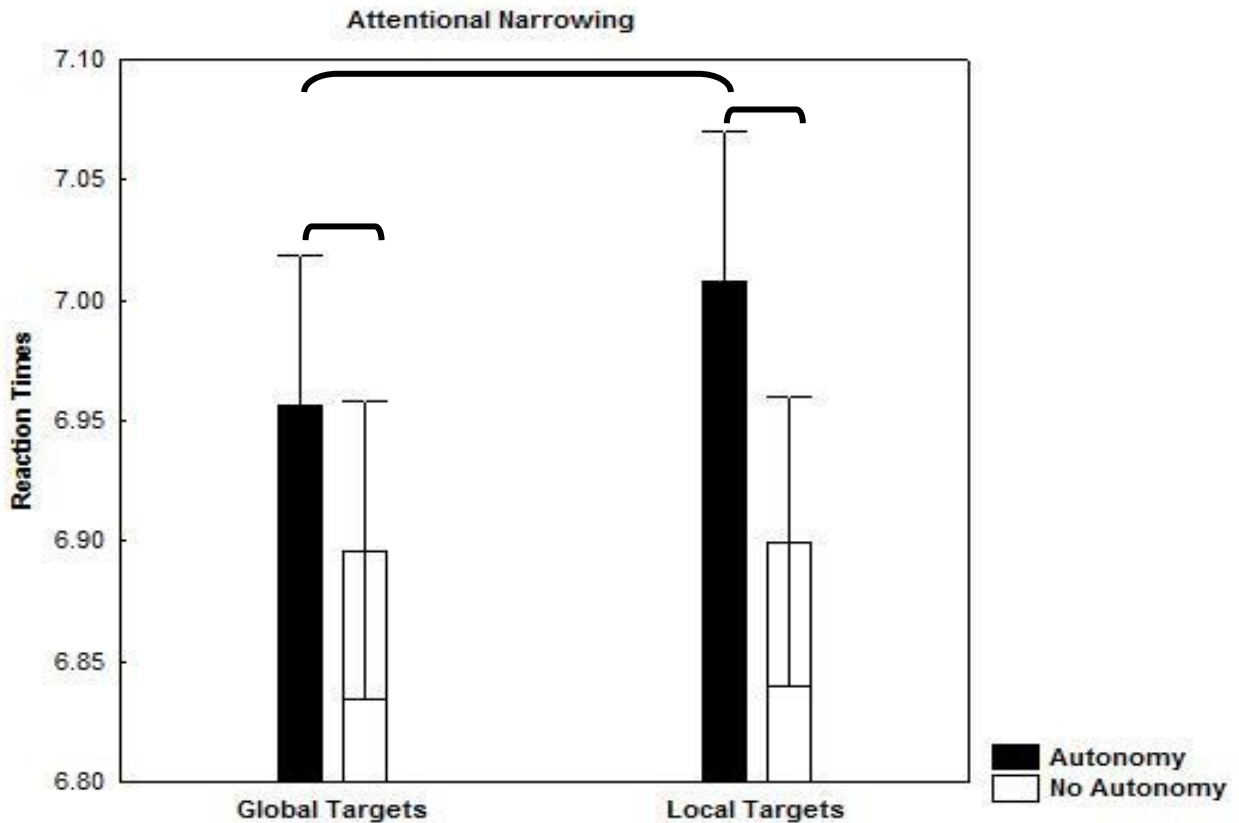
### Manipulation Checks

A series of dependent-samples *t*-tests were used to test perceived choice over tasks, choice over feedback, self-reported effort, and task enjoyment to the autonomy vs. no autonomy conditions. Participants felt they had more task-choice during the autonomy ( $M = 6.28$ ,  $SD = 1.52$ ) than the no autonomy condition ( $M = 2.28$ ,  $SD = 2.25$ ),  $t(44) = 9.68$ ,  $p < .000001$ ,  $d = 2.08$ . Participants also felt they had more feedback-choice during the autonomy ( $M = 5.75$ ,  $SD = 1.79$ ) than the no autonomy condition ( $M = 2.75$ ,  $SD = 2.11$ ),  $t(44) = 7.37$ ,  $p < .000001$ ,  $d = 1.53$ . Participants did not self-report putting more effort in the autonomy than the no autonomy condition,  $t(44) = 0.57$ ,  $p < .57$ . Finally, when asked about enjoyment, participants reported more enjoyment for the autonomy ( $M = 3.91$ ,  $SD = 1.53$ ) than the no autonomy condition ( $M = 3.40$ ,  $SD = 1.51$ ),  $t(44) = 2.86$ ,  $p < .007$ ,  $d = 0.34$ . These results suggest the manipulation of autonomy was consistent with making participants feel like they had a choice over the task and feedback and that participants enjoyed the autonomy task more. However, participants did not self-report any differences in effort between the two tasks.

### Attentional Narrowing

A 2 (Autonomy vs. No Autonomy) X 2 (Global vs. Local) repeated measures ANOVA revealed a marginal interaction,  $F(1, 41) = 3.04$ ,  $p < .09$ ,  $\eta_p^2 = .07$  (see Figure 7). Post-hoc analyses revealed RTs were faster to global ( $M = 6.96$ ,  $SD = 0.40$ ) than local ( $M = 7.00$ ,  $SD = 0.40$ ) targets in the autonomy condition ( $p < .02$ ,  $d = .13$ ). RTs were faster to the no autonomy global ( $M = 6.90$ ,  $SD = 0.40$ ) than autonomy global ( $M = 6.96$ ,  $SD = 0.40$ ) targets ( $p < .004$ ,  $d =$

.15). RTs were faster to the no autonomy local ( $M = 6.90, SD = 0.39$ ) than autonomy local ( $M = 7.00, SD = 0.40$ ) targets ( $p < .000003, d = .25$ ). There was no difference in RTs between the no autonomy global and local conditions ( $p > .84$ ). These results suggest there was greater attentional broadening during the autonomy trials than during the no autonomy trials.

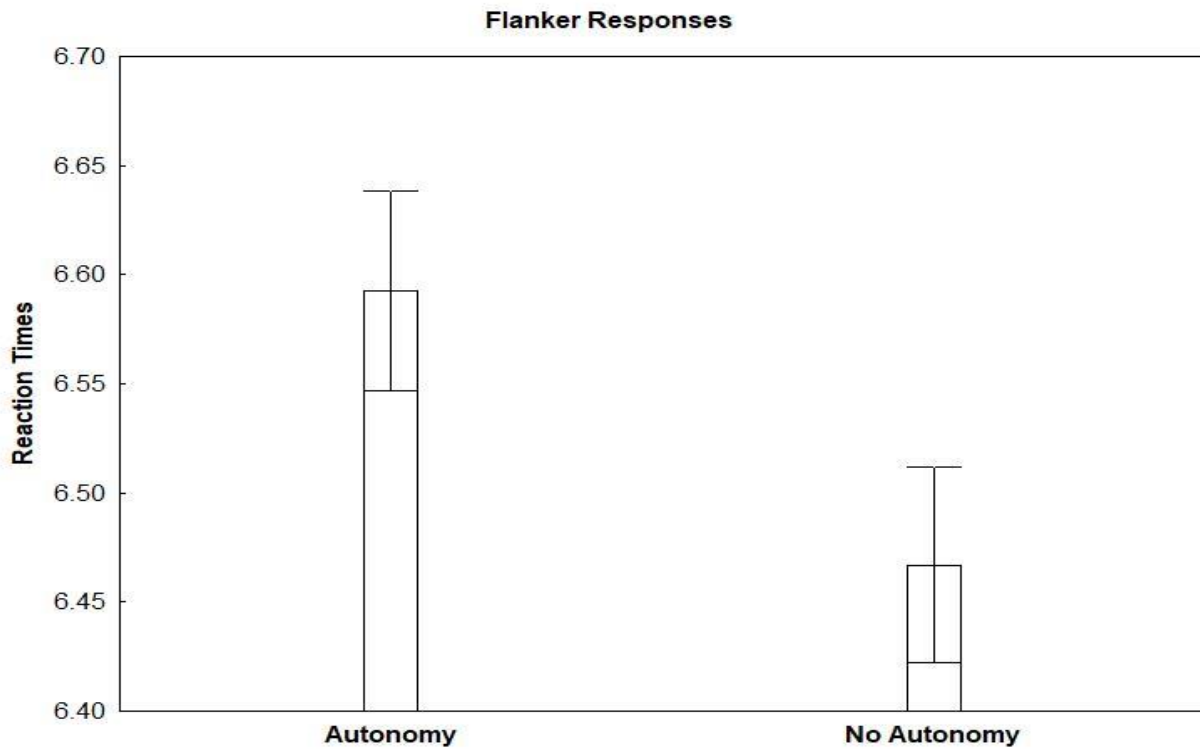


**Figure 7.** Attentional narrowing reflected by Navon letter reaction times. Brackets indicate significant differences between conditions. Error bars represent standard errors from the mean.

### Flankers

A repeated measures ANOVA revealed participants made faster responses during the no autonomy ( $M = 6.48, SD = 0.30$ ) than autonomy ( $M = 6.59, SD = 0.31$ ) conditions,  $F(1, 44) = 6.59, p < .02, \eta_p^2 = .14$  (see Figure 8). It seems the simplicity of the flanker task was still able to show a difference between conditions (Huizinga et al., 2006). Specifically, these results unexpectedly suggest participants did not perform better in the autonomy (vs. no autonomy)

conditions. This can be attributed to the potential interference of a broadened attentional scope reflected from the RTs to Navon letters in the autonomy condition.



**Figure 8.** Flanker reaction times. Error bars represent standard errors from the mean.

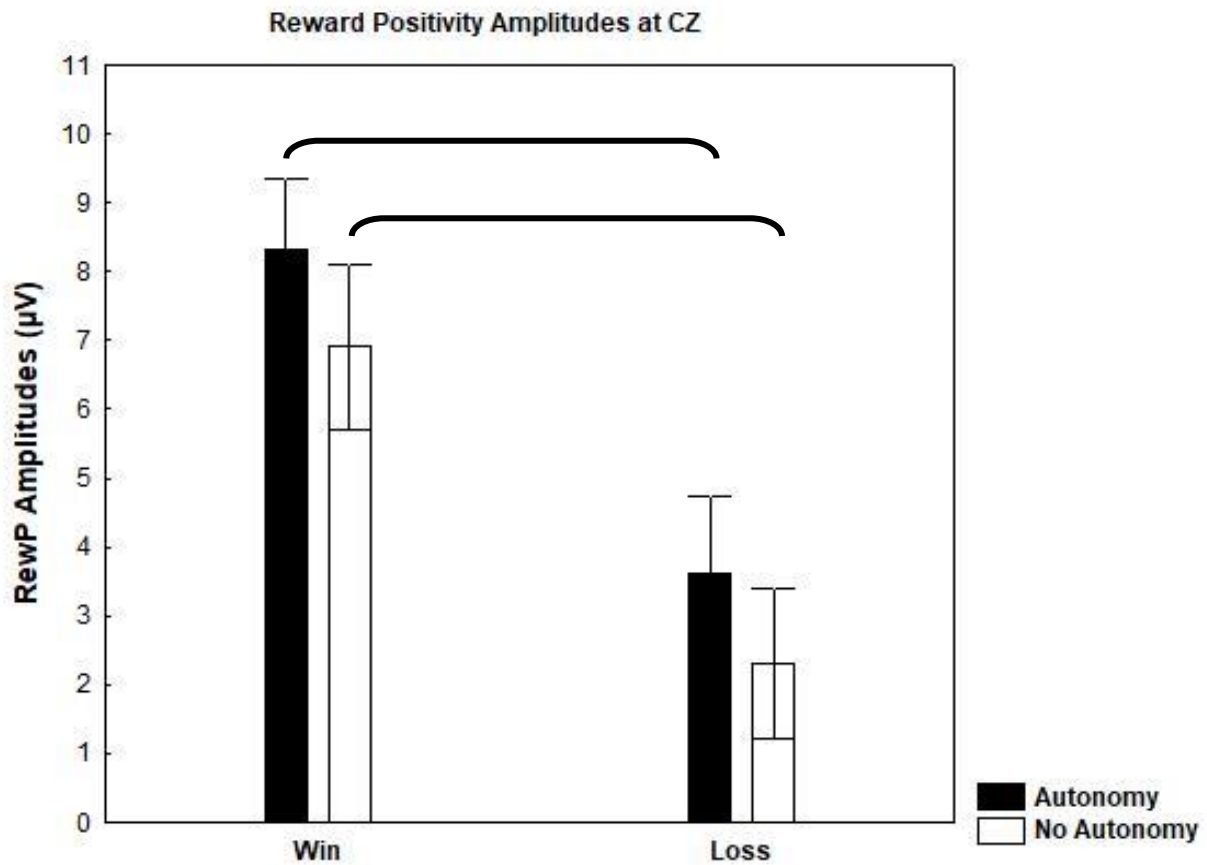
### Beta Suppression

A repeated measures ANOVA revealed beta suppression was not enhanced during the autonomy cues ( $M = 1.58$ ,  $SD = 0.97$ ) than no autonomy cues ( $M = 1.66$ ,  $SD = 0.98$ ),  $F(1, 38) = 2.83$ ,  $p < .11$ ,  $\eta_p^2 = .07$ . This suggests there was no significant difference in neural motor-action preparation between autonomy and no autonomy conditions.

### Reward Positivity

For site CZ, a 2 (Autonomy vs. No Autonomy) X 2 (Win vs. Loss) repeated measures ANOVA revealed a significant main effect for autonomy vs. no autonomy,  $F(1, 36) = 5.45$ ,  $p < .03$ ,  $\eta_p^2 = .13$ , where RewP amplitudes were greater for autonomy than no autonomy. There was a main effect for win vs. loss,  $F(1, 36) = 31.00$ ,  $p < .000004$ ,  $\eta_p^2 = .46$ , where RewP amplitudes

to wins were greater than losses. The interaction was not significant (see Figure 9). RewP amplitudes were greater to autonomy wins ( $M = 8.31, SD = 6.27$ ) than autonomy losses ( $M = 3.60, SD = 6.93; p < .000001, d = .71$ ). Amplitudes were also greater to no autonomy wins ( $M = 6.90, SD = 7.34; p < .000002, d = .65$ ) than no autonomy losses ( $M = 2.31, SD = 6.69; p < .000002, d = .65$ ). With the comparison of interest, autonomy wins ( $M = 8.31, SD = 6.27$ ) were only marginally greater than no autonomy wins ( $M = 6.90, SD = 7.34; p < .08, d = .21$ ). Finally, autonomy losses ( $M = 3.60, SD = 6.93$ ) were marginally greater than no autonomy losses ( $M = 2.31, SD = 6.69; p < .10, d = .19$ ).



**Figure 9.** Reward Positivity amplitudes for site CZ. Brackets indicate significant differences between conditions. Error bars represent standard errors from the mean.

## Emotion Ratings

Exploratory analyses, in light of the current results, were conducted with the emotion ratings to the stimuli of interest (initial trial cues and win stimuli in the autonomy and no autonomy conditions) for this study. Participants indicated their emotions (*sad, glad, nervous, enthusiastic, happy, excited, angry, down, mad, and anxious*) to these stimuli. Positive emotions low in approach motivation (*glad* and *happy*) were averaged and compared to positive emotions high in approach motivation (*enthusiastic* and *excited*) for autonomy and no autonomy conditions. A 2 (Autonomy vs. No Autonomy) X 2 (Positive Affect: High vs. Low) repeated measures ANOVA for participant self-reported emotions during trial cues revealed a marginal interaction,  $F(1, 44) = 2.04, p < .16, \eta_p^2 = .16$ . Post-hoc analyses revealed that participants reported feeling greater positive low-approach affect in the autonomy ( $M = 3.64, SD = 1.79$ ) than in the no autonomy condition ( $M = 3.01, SD = 1.84; p < .0004, d = .35$ ). Positive high-approach affect in the autonomy condition ( $M = 3.38, SD = 1.64$ ) was higher than in the no autonomy condition ( $M = 3.02, SD = 1.78; p < .02, d = .21$ ). In the autonomy condition, positive low-approach affect ( $M = 3.64, SD = 1.79$ ) was marginally higher than positive high-approach affect ( $M = 3.37, SD = 1.64; p < .06, d = .16$ ). There were no differences in positive affect in the no autonomy condition ( $p > .90$ ).

A 2 (Autonomy vs. No Autonomy) X 2 (Positive Affect: High vs. Low) repeated measures ANOVA for participant self-reported emotions during winning feedback revealed a marginal main effect for positive affect type,  $F(1, 44) = 3.19, p < .09, \eta_p^2 = .07$ , where participants reported marginally greater low-approach ( $M = 4.69, SD = 1.76$ ) than high-approach ( $M = 4.50, SD = 1.82$ ) positive affect for both conditions. There was no interaction. However, further follow-up analyses to the winning feedback revealed that participants reported feeling

higher low-approach positive affect ( $M = 4.79, SD = 1.91$ ) than high-approach positive affect ( $M = 4.57, SD = 1.92$ ) in the autonomy condition ( $p < .03, d = .11$ ). Participants also reported feeling greater low-approach positive affect in the autonomy condition ( $M = 4.79, SD = 1.91$ ) than in the no autonomy condition ( $M = 4.60, SD = 1.79; p < .04, d = .10$ ). They further reported feeling marginally greater low-approach positive affect ( $M = 4.60, SD = 1.79$ ) than high-approach positive affect ( $M = 4.43, SD = 1.79$ ) in the no autonomy condition ( $p < .07, d = .09$ ). Taken together, the emotional rating results for the initial trial cues and winning feedback seem to suggest the positive affect experienced during the study may have been lower in approach-motivational intensity during the autonomy condition.



## DISCUSSION

The aim of the current studies was to examine the motivational intensity within intrinsic motivation. Study 1 used social comparison to manipulate performance expectancy, a manipulation of intrinsic motivation (Wulf & Lewthwaite, 2016). Results revealed that manipulating this form of intrinsic motivation narrowed attentional scope, enhanced motor-action preparation, and increased RewP amplitudes during feedback processing. These findings are similar with past work using manipulations of extrinsic motivation (e.g., monetary rewards). Specifically, perceiving that a task would be difficult enhanced a narrowed attentional scope, a cognitive consequence that reflects a more motivated state (Gable & Harmon-Jones, 2010b). Study 1 results also show that greater perceived difficulty suppressed beta activity over motor cortical areas. Lastly, we found more positive neural feedback processing for wins in the difficult expectancy condition. In sum, it appears that enhancing intrinsic motivation by manipulating social performance expectancy evoked high intensity motivation, similar to the cognitive and neural consequences evoked by extrinsic rewards such as desserts and money.

Study 2 examined another form of intrinsic motivation by manipulating task autonomy (Wulf & Lewthwaite, 2016). Results showed autonomy broadened attentional scope, reduced task performance as reflected by slower RTs, no significant difference in enhanced motor-action preparation, and only marginally increased RewP amplitudes during feedback processing. These results suggest the manipulation of autonomy evoked low intensity motivation. These results were similar to past studies using intrinsic manipulations of autonomy that seem to evoke low intensity motivational states (Black & Deci, 2000; Demir et al., 2011; O'Donnell et al., 2013).

Current findings on attentional narrowing show mixed support for intrinsically motivated states' role in enhancing attention. Recent studies and reviews have stated attentional changes that enable better performance take place as a result from intrinsically motivated states (Wulf & Lewthwaite, 2016). Based on previous work, this would suggest that intrinsically motivated states should narrow attentional scope in order to fixate attentional resources on the task at hand (Gable & Harmon-Jones, 2008; Gable et al., 2016a; Gable et al., 2016b; Harmon-Jones, Gable, & Price, 2013) and guide subsequent behavior to enhance performance (Bollinger, Rubens, Zanto, & Gazzaley, 2010; Shomstein & Johnson, 2013). The results of the two studies suggest that intrinsic motivation can evoke high or low motivational states. Not all intrinsically motivated states have the same motivational intensity. Social performance expectancy and autonomy evoke high and low motivational states, respectively. This was evident in the narrowing of attention that occurred for performance expectancy. On the other hand, autonomy broadened attentional scope.

Another focus of these studies was also on whether enhanced intrinsic motivation influenced a behavioral measure of performance similarly to extrinsic motivation and previous intrinsic motivation literature. However, the current studies show mixed support for these. Study 1 did not find differences in behavioral flanker RTs between conditions. This is could be likely due to the flanker response demands being low, and unlikely to be made much faster by the manipulation of high motivational intensity elicited by performance expectancy (Huizinga, Dolan, & Van der Molen, 2006). It is also worth noting that flanker responses in Study 1 had a high degree of success, so perhaps some ceiling effects occurred for this study. Also, because we were interested in participants' *perceived* level of difficulty on the task, we did not change the actual difficulty level of the task. This means there were no further demands (other than the

instructions) that would add the time pressures that often reduce response times and success rates (Dambacher & Hübner, 2015; Behan, Stone, & Garavan, 2015). Prior research has also found null effects on flanker RTs even when attentional narrowing effects are strong due to greater motivational intensity across several experiments (Threadgill & Gable, 2018).

On the other hand, Study 2 did show differences in performance between conditions in the opposite direction (no autonomy had better performance). These results can perhaps be attributed to the lack of attentional narrowing in the autonomy condition as well. The attentional results are indicative of a diminished engagement in the task due to the broadened attentional scope experienced in the autonomy condition.

Prior studies on beta suppression and motivation have strictly focused on monetary contexts, not intrinsically motivated states (Gable et al., 2016b; Meadows et al., 2016a; Meyniel & Pessiglione, 2014). Results for Study 1 indicate that beta suppression was indeed enhanced during difficult performance expectancy, reflecting greater motivational intensity. However, results for Study 2 did not show enhanced beta suppression during autonomy. These studies indicated different intrinsically motivated states affect motor-action preparation differently due to their influence on motivational intensity. The results for both studies also expand research on neural motor-action preparation by suggesting beta suppression may be involved in a broader motivational context in which some forms of intrinsic motivation (i.e., social expectancy of difficult trials) enhance motor-action preparation similarly to extrinsically motivated states. This is perhaps because expecting a task to be difficult and outperforming those who did poorly on the task enhances the value of the goal (Mirabella, 2014). However, it seems that not all forms of intrinsic motivation can be generalized to enhance motor-action preparation in cortical areas, as indicated by neural motor-action preparation during Study 2.

Broadly, these results also provide evidence suggesting some forms of intrinsic motivation that enhance motivational intensity also influence the gating role of beta activity for future motor movement (van Wilk, Beek, & Daffertshorster, 2012). This gating role is important for motor actions because beta activity seems to inhibit voluntary motor movements (Engel & Fries, 2010). Difficult task expectancy seems to help with the gating role of beta activity, even though beta suppression may not necessarily mediate actual performance (Meyniel & Pessiglione, 2014).

Results also revealed that our participants also had greater RewP amplitudes for difficult wins vs. easy wins. This is consistent with past work on reward studies that suggest conditions with greater motivational intensity enhance RewP amplitudes (Foti et al., 2011; Foti et al., 2015; Meadows et al., 2016b; Threadgill & Gable, 2016). Our findings also extend the study of intrinsic motivation by showing that intrinsic motivational contexts of performance expectancy cause neural feedback processing to function similarly to extrinsic motivation. Greater RewP amplitudes for difficult wins may be reflecting greater dopaminergic activity that enhances performance monitoring within this intrinsic context as well (Carlson, Foti, Mujica-Parodi, Harmon-Jones, & Hajcak, 2011; Holroyd & Coles, 2002). Not surprisingly we also found a strong difference between wins and losses with intrinsic motivation (Foti et al, 2011; Foti et al., 2015). Study 2 showed marginally similar results to those of Study 1. However, the extent to which feedback is processed neurologically was not as strong, which may have also been a result of lower motivational intensity. This further suggests that intrinsic motivation is perhaps more complex and should not be as generalized as the intrinsic motivation literature makes it seem (Wulf & Lewthwaite, 2016; Eitam et al., 2013), particularly because autonomy did not enhance motivational intensity.

Taken together, RewP results suggest that some intrinsic motivators can also have an effect in the same neural pathways of feedback processing and reinforcement learning, as reflected by the RewP deflection. This ERP evidence is important because it suggests the RewP may be one of the underpinnings within theories and studies in self-determination (Ryan & Deci, 2000) and learning (Wulf & Lewthwaite, 2016). Because the RewP reflects performance monitoring, it may also be involved in the subsequent advantages of some intrinsic motivation paradigms (Deci et al., 2017).

Taken together, the results of these studies on manipulations of intrinsic motivation seem to suggest that not all intrinsic motivations are created equal and may be more complex than extrinsic motivators. There may be various reasons as to why intrinsic motivations might not affect motivation in the same ways. One potential reason to make note of is the extent to which positive affect high or low in approach motivation is affected by manipulations of intrinsic motivation. Emotional ratings for these two studies allude to differences in motivational intensity. Specifically, it seems that expectancy of difficult trials may have produced the high-approach motivation necessary for attentional narrowing, beta suppression, and increases in RewP to occur like in extrinsic motivational paradigms (Gable et al., 2016b; Threadgill & Gable, 2016). On the other hand, autonomy did not show the same pattern. It seems that autonomy increased enjoyment for the task and low-approach motivational intensity. This is corroborated by the broadening of attention that occurred during the initial trial cues for every trial. Research shows that low-approach motivation broadens attentional scope (Fredrickson & Branigan, 2005; Gable & Harmon-Jones, 2008; Gable & Harmon-Jones, 2010b). Perhaps, intrinsic motivations low in approach-motivation still have benefits to performance and learning in other ways that could perhaps be more tied to low-approach positive affect. However, the autonomy paradigm

studied in Study 2 did not show behavioral benefits and only marginal neural benefits that were measured in this study.

In sum, intrinsic motivation associated with difficult expectancy narrowed attentional scope, enhanced cortical motor-action preparation, and increased neural feedback processing. This reflected enhanced high-motivational intensity. These effects were comparable to that of extrinsic rewards (Gable et al., 2016a, 2016b, Threadgill & Gable, 2016). However, these effects were not the same for autonomy, another form of manipulating intrinsic motivation. Autonomy enhanced low-motivational intensity, as reflected by broadened attentional scope, diminished performance to a flanker task, and lack of differences in neural measures of motor-action preparation and feedback processing. These studies supported the need for integrating some of the behavioral and phenomenological observations of intrinsic motivation with empirical physiological measures (Di Domenico & Ryan, 2017). It helped to expand some of the current literature by suggesting intrinsic motivation is perhaps more complex than some of the literature suggests. Specifically, because performance expectancy and autonomy did not influence attention, performance, motor-action, and feedback processing in similar ways. Narrowing down the attentional and neurological effects of different forms of intrinsic motivation seems crucial for future research. Doing so can help us to further understand both similarities and differences between intrinsic and extrinsic motivations by using a wider range of behavioral and physiological measures.

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## APPENDIX

### HUMAN SUBJECTS APPROVAL FOR BOTH PHYSIOLOGICAL STUDIES



August 20, 2018

Philip Gable, Ph.D.  
Associate Professor  
Department of Psychology  
College of Arts and Sciences  
The University of Alabama  
Box 870348

Re: IRB # 12-OR-076-R7 "Personality and Physiology"

Dear Dr. Gable:

The University of Alabama Institutional Review Board has granted approval for your renewal application. Your renewal application has been given expedited approval according to 45 CFR part 46. You have also been granted the requested waiver of one element of informed consent as well as a waiver of documentation of informed consent. Approval has been given under expedited review category 7 as outlined below:

*(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.*

Your application will expire on August 19, 2019. If your research will continue beyond this date, complete the relevant portions of the IRB Renewal Application. If you wish to modify the application, complete the Modification of an Approved Protocol Form. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, complete the appropriate portions of the IRB Study Closure Form.

Please use reproductions of the IRB approved stamped consent form to obtain consent from your participants.

Should you need to submit any further correspondence regarding this proposal, please include the above application number.

Good luck with your research.

Sincerely,

Ca:  
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Office for Research Compliance

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205-348-8461 | Fax 205-348-7189 | Toll Free 1-877-820-3066