

Neural and Attentional Correlates of Intrinsic Motivation Resulting from Social Performance Expectancy

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Abstract—Some models of motivation distinguish between intrinsic and extrinsic motivation. While past work has examined the neural and cognitive correlates of extrinsic motivation, research on intrinsic motivation has relied primarily on behavioral measures of performance and learning. In particular, no past work has examined the neural and cognitive correlates of social performance expectancy, which is linked to intrinsic motivation. The current study manipulated expectancy of difficult (vs. easy) trials on a cued flanker task and assessed attentional scope and performance. EEG was used to examine motor-action preparation as measured by suppression of beta band activity over the motor cortex and feedback processing as measured by the Reward Positivity (RewP). Results revealed expectancy of difficult (vs. easy) trials narrowed attentional scope, reduced beta activity over the motor cortex, and enhanced RewP amplitudes to win feedback. These findings suggest that enhancing intrinsic motivation through expectancies of positive social comparison engages similar neural and cognitive correlates as extrinsic motivators high in motivational intensity. © 2019 IBRO. Published by Elsevier Ltd. All rights reserved.

Key words: intrinsic motivation, beta activity, reward positivity, attentional scope.

INTRODUCTION

Motivation is critical in dictating an individual's effort to accomplish or attain a goal by activating the intent or the physical movement towards (approach) or away (withdraw) from something (Harmon-Jones and Gable, 2017). Some models of motivation distinguish between two types of motivation: intrinsic and extrinsic (Ryan and Deci, 2000). Broadly, extrinsic motivation is the drive to act, or behave in a certain way with the purpose of attaining or experiencing some external consequence (Deci et al., 2017). On the other hand, intrinsic motivation is primarily driven by interest or inherent satisfaction for some activity (Di Domenico and Ryan, 2017).

The distinction between intrinsic motivation and extrinsic motivation is often investigated in relationship to an individual's values and well-being (Deci et al., 1999; Ryan and Deci, 2000; Deci et al., 2001; Deci and Ryan, 2008). Intrinsic motivation is 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 and Deci, 2000; Ryan and Deci, 2017). Intrinsically motivated states may also enhance goal accomplishment, as intrinsically motivated activities lead to less physical burnout, emotional exhaustion, and make individuals feel like they perform better (Richter et al., 2002; Kuvaas, 2009; Fernet et al., 2010).

Despite much past work examining the behavioral outcomes of intrinsic motivations, little work has investigated the neural correlates of expectancy as an intrinsic motivator (Di Domenico and Ryan, 2017). Past work has primarily focused on intrinsic motivation and neural correlates tied to manipulations of autonomy, confederate manipulations, or conceptually different neural correlates of motivation (Murayama et al., 2010; Legault and Inzlicht, 2013; Di Domenico et al., 2016; Meng et al., 2016; Lee and Reeve, 2017). More research on different forms of intrinsic motivation is still needed in order to further examine the neural correlates of intrinsic motivation (Di Domenico and Ryan, 2017).

Motivational intensity in motivation

Motivational states vary in their intensity; some states are high in motivational intensity, whereas others are low in motivational intensity (Gable and Harmon-Jones, 2010b; Harmon-Jones et al., 2013b). High and low motivational states vary in their influence on cognitive scope, neural

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Abbreviations: EEG, Electroencephalography; ERP, Event Related Potential; RewP, Reward Positivity; RTs, Response Times; ms, Milliseconds.

substrates, and goal pursuit. [Gable and Harmon-Jones \(2008\)](#) proposed the motivational intensity model of cognitive scope, by demonstrating that increases in motivational intensity, independent of affective valence, narrow cognitive scope and activate goal-directed behavior ([Price and Harmon-Jones, 2010](#); [Gable and Harmon-Jones, 2010b](#); [Gable and Harmon-Jones, 2013](#); [Harmon-Jones et al., 2012](#); [Harmon-Jones et al., 2013a](#); [Gable et al., 2015](#); [Zhou and Siu, 2015](#)). Functionally, an organism will narrow cognitive resources to focus on the desired object or goal. In support of this model, research finds that greater motivational intensity towards primary rewards (e.g., delicious desserts) or secondary rewards (e.g., money) narrows attentional scope, breadth of memory, and shortens the perception of time ([Knutson et al., 2000](#); [Harmon-Jones and Gable, 2008](#); [Gable and Harmon-Jones, 2010a, 2011](#); [Gable and Poole, 2012](#); [Hicks et al., 2015](#)).

Motivational intensity and cognitive scope

States high in motivational intensity cause a more narrowed attentional scope. Prior studies show that states high in motivational intensity facilitate faster responses to local elements of [Navon's \(1977\)](#) letters. 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. The narrowing of attentional scope is a cognitive consequence of enhanced motivation. States high in motivational intensity are manipulated using a variety of extrinsic motivators such as viewing pictures and films of appetitive desserts ([Gable and Harmon-Jones, 2008](#)), viewing pictures of alcoholic beverages ([Gable et al., 2016a](#)), and having the potential to receive monetary rewards ([Gable and Harmon-Jones, 2010a, 2011](#)). In sum, a narrowed attentional scope causes an organism to focus cognitive resources on obtaining a goal or object.

Beta suppression and motivational intensity

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 et al., 2000](#)). This increase in activation reduces beta and alpha wave activity over these regions ([Babiloni et al., 2015](#); [McFarland et al., 2000](#); [Pfurtscheller et al., 2005](#)). The suppression of beta band activity (13–30 Hz) measured by electroencephalography (EEG) is frequently used for examining motor-action preparation before an incentivized stimulus ([Doyle et al., 2005b](#); [Meadows et al., 2016a](#); [Gable et al., 2016b](#); [Sanes and Donoghue, 1993](#)).

Situations that involve extrinsic rewards like money, reduce beta activity, relative to states in which no monetary gain can be achieved ([Gable et al., 2016b](#)). [Meyniel and Pessiglione \(2014\)](#) found beta activity was diminished when reward levels were increased. Reduced beta activity leads to enhanced preparation for actions, typically manifested by faster reaction times (RTs; [Doyle et al., 2005a](#); [Gable et al., 2016b](#); [van Wijk et al., 2009](#)). In sum, various manipulations of extrinsically motivating states appear to enhance motor-action preparation. However, it could be possible that extrinsic motivators

only reduce beta activity because they have exogenous objects or goals to move towards. As researchers have only examined beta activity in the context of extrinsic rewards, this possibility remains unanswered.

Reward positivity and motivational intensity

The Reward Positivity (RewP) is an event-related potential (ERP) component that reflects appraisal of positive performance feedback ([Proudfit, 2015](#); [Threadgill and Gable, 2016](#); [Meadows et al., 2016b](#)). This component consists of a positive deflection in the ERP wave at midline sites that occurs roughly 230–350 ms after feedback onset. RewP wave amplitudes are significantly larger when an individual is given positive feedback of monetary gains ([Holroyd et al., 2006](#); [Holroyd et al., 2011](#); [Weinberg et al., 2014](#)). [Meadows et al. \(2016b\)](#) found that RewP amplitudes increased when reward magnitude increased. Larger RewP amplitudes are also related to greater trait approach-motivation measures ([Yeung et al., 2005](#); [Lange et al., 2012](#); [Bress and Hajcak, 2013](#); [Angus et al., 2015](#)) and autonomous task choices ([Meng and Ma, 2015](#)). Broadly, this literature suggests that motivation enhances feedback-processing, as reflected by the RewP.

The current study

Past work supporting the motivational intensity model is limited in that empirical work has primarily examined motivational states manipulated through strong extrinsic motivators (e.g., pictures of delicious desserts, or monetary rewards). Thus, most past work demonstrating that states high in motivational intensity narrow cognitive scope, enhance action preparation (suppress motor beta activity), and enhance feedback processing (larger RewP) could be interpreted as being due to extrinsic motivators. Perhaps the focus on the extrinsically desired object or reward resulted in greater attentional narrowing and action preparation, as opposed to being caused by motivational intensity, per se. The present research was designed to address these gaps in past work by examining the influence of intrinsic motivation on cognitive scope, action preparation, and feedback processing.

Based on evidence suggesting that intrinsic motivators, such as performance expectancy, can enhance motivation, the current study sought to examine whether manipulating performance expectancy would also influence cognitive and neurological markers associated with enhanced extrinsic motivation. The current study aimed to examine the extent to which social performance expectancy enhances the motivational processes of attentional narrowing, motor-action preparation, and performance feedback processing.

Research shows expectancy of task performance, based on social comparisons, can enhance the capability for future task performance, even when performance feedback is false ([Lewthwaite and Wulf, 2010](#); [Ávila et al., 2012](#); [Kantak and Winstein, 2012](#); [Wulf et al., 2012](#)). Specifically, comparisons of performance in relation to how others perform provide an effective way for individuals to evaluate their competence ([Wulf and Lewthwaite, 2016](#)), a psychological need that drives intrinsic motivation ([Deci et al., 1999](#)). These expectations may act as motivators because positive self-evaluations

about performance (in relation to others) enhance motivation to continue to perform and learn (Lewthwaite and Wulf, 2010). Performance in relation to others is internalized and tied to self-efficacy, making expectancy intrinsically oriented (Deci et al., 2017; Di Domenico and Ryan, 2017). The perceived level of difficulty also enhances intrinsic motivation. Greater perceived difficulty demands more effort and can make success feel more valuable (Inzlicht et al., 2018). Task difficulty also enhances interest and attention (Wang et al., 2017), as well as neural activity to feedback, as measured by the RewP (Ma et al., 2014).

The current study manipulated performance expectancy by giving participants the expectancy that a flanker reaction time task (Eriksen and Eriksen, 1974) would be difficult or easy. We hypothesized that difficult (vs. easy) expectancies on a task would enhance intrinsic motivation by offering an opportunity to outperform a social comparison group. Performing well, as compared to a social group meets a basic psychological need of positive self-evaluation. This is especially true when there is an absence of social recognition and the motivation to outperform others is entirely intrinsic. Participants were not recognized in any way for their success, and their performance was unmotivated by any extrinsic factor. We predicted that the expectancy of a difficult task would enhance motivational intensity, as compared to the easy task and should cause greater attentional narrowing, as measured by the Navon (1977) letters task. Greater intrinsic motivation from difficult (vs. easy) trials should cause greater beta suppression (Gable et al., 2016b), and greater RewP amplitudes to wins (Meng and Ma, 2015; Threadgill and Gable, 2016; Meadows et al., 2016b).

EXPERIMENTAL PROCEDURES

Participants

Forty undergraduate introductory psychology students participated for partial course credit. Data collection was set to stop at the end of the semester. To be included in the study, participants had to be at least 18 years old and be right-handed. Participant handedness was assessed using a 13-item checklist (Gable and Poole, 2014; Neal and Gable, 2017). For this checklist, participants were asked to indicate which hand (right, left, or both) they used to perform day-to-day tasks (e.g., use scissors, write, draw, etc.). Participants were classified as right-handed if they reported doing no more than one activity with their left hand.

Procedure

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 and Eriksen, 1974). Trials ($n = 96$) were broken up into eight blocks of 12 trials each. Four of these blocks generated the expectancy of being difficult trials to beat and the other four 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, we created expectancies based on a social comparison by ostensibly showing past performance of others on each task (Lewthwaite and Wulf, 2010; Ávila et al., 2012; 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, offering participants the opportunity to outperform other students if they engaged more effort than the average participant. Easy blocks demonstrated approximately a 90% success rate, presenting participants with the expectation of doing just as well or worse than the average student with only average effort. Before beginning the blocks of trials, participants were given practice trials to get accustomed to the task and to demonstrate the task did not require greater ability, because it was simple. To further encourage participants to engage more effort in the task, participants were told they needed to be both accurate and fast enough to successfully win the trials. No reaction time threshold for success was given. After the graphs, participants were asked to state the percentage of trials they expected to get correct on that block. Participants then completed the block of trials.

Each trial began with a cue presented at the center of the screen for 2000 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 were 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 was used in various motivation studies (Gable and Harmon-Jones, 2008; Hicks et al., 2012; Hicks et al., 2015; Gable et al., 2016b). 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 and 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. This task was used because it is a

relatively simple task that does not require unique competency to complete. Responses to flankers were made by pressing the left and right shift keys on a keyboard.

Following their responses to each flanker, positive or negative feedback was shown for 2000 ms. A green “checkmark” was shown for positive feedback (indicating they were successful on the trial) and a red “X” was shown for negative feedback (indicating they were unsuccessful on 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 50% of trials with correct responses, in both conditions regardless of flanker task reaction time (see Fig. 1 for a sample trial sequence). This feedback was informational, providing information as to whether there was success or failure (Houffort et al., 2002). Trial presentation length, tasks, and outcomes were identical between the easy and difficult conditions.

After each block, participants reported their success rate for that block. These questions served as manipulation checks that would shed light on whether or not participants thought they outperformed (or underperformed) the social comparison shown in the graph (prior to the start of the block). These questions were presented as scales ranging from 1 (10%–20%) to 9 (91%–100%).

The study was completed at a computer using Inquisit Lab stimulus presentation software (Inquisit 4.0.10, 2015). Consistent with much past work and guidelines for examining reaction time data (Fazio, 1990), reaction times were log transformed to bring the data closer to a normal distribution. Past work suggests that raw RTs are susceptible to “cognitive noise” that increase RT standard deviations (Robinson and Tamir, 2005), but this noise does not occur or is reduced with log-transformed RT data. Trials with incorrect responses for the Navon letters (<8% and <9% respectively) and trials for which RTs, beta

suppression, and RewP amplitudes were more than 3 standard deviations from the mean were discarded ($\leq 7.5\%$ of the sample).

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. During recording, data were referenced to the left earlobe, and electrode impedances were kept under 5 k Ω (with homologous sites within 1 k Ω 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 (Gratton et al., 1983). Data were then visually inspected a second time to ensure proper correction.

During cue presentation, epochs were every 1024 ms for each trial and were extracted using a Hamming window (50% taper of distal ends), with consecutive epochs overlapped by 50%. Data were re-referenced offline using an average ears reference. Power spectra (1 Hz bins) 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 (McFarland et al., 2000; Muthukumaraswamy et al., 2004; Pfurtscheller et al., 2005; R  ther et al., 2014; Gable et al., 2016b). Per participant, there was an average of 108 epochs for the difficult cues and 111 epochs for the easy cues after artifact rejection.

Consistent with past work analyzing the RewP, data were epoched 100 ms prior to feedback onset until 1200 ms after

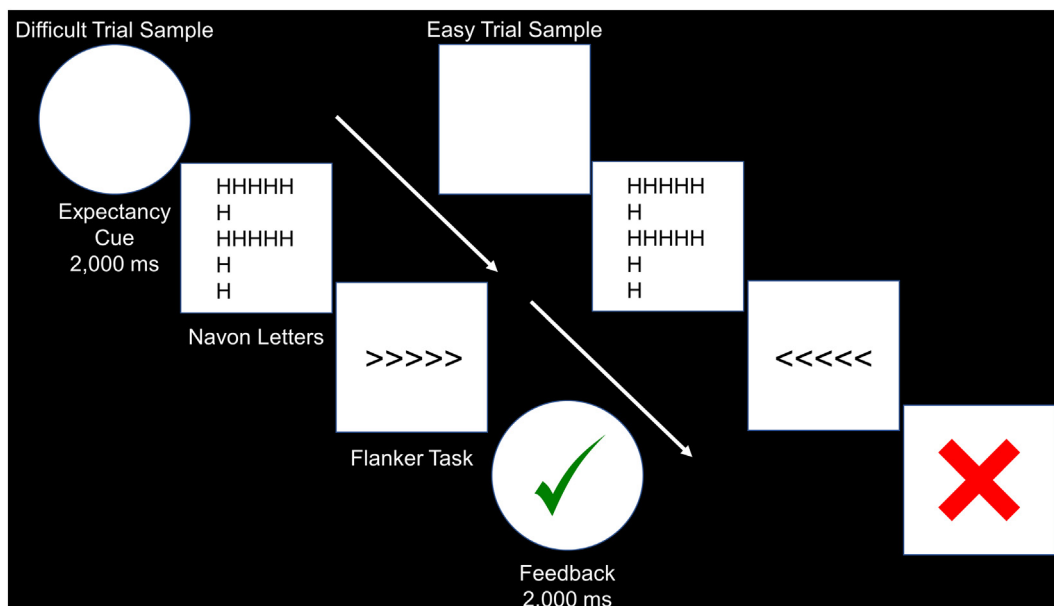


Fig. 1. Sample trials. There was a variable ISI between 500 and 700 ms after each initial cue, Navon letter, and flanker for each trial.

feedback onset and low-pass filtered at 35 Hz (Threadgill and Gable, 2016). Mean waveforms for each feedback type were created and baseline corrected based on the pre-stimulus activity (100 ms). Trials with errors were excluded from ERP analyses. The RewP mean amplitudes were assessed for positive and negative feedback at midline sites Cz, CPz, and Pz with a window of 220–300 ms after feedback onset (Baker and Holroyd, 2011; Foti et al., 2011; Foti et al., 2012; Weinberg et al., 2014; Proudfit, 2015; Gable et al., 2016b; Meadows et al., 2016b; Williams et al., 2017). Consistent with this past work we assessed RewP amplitude where outcome valence was maximal, and found that outcome valence was maximal at sites Cz and CPz.¹ The RewP was measured as the mean EEG activity from sites Cz and CPz. Per participant, there was an average of 16 trials that were averaged for the RewP in both the difficult and easy conditions after artifact rejection.

Statistical analyses

Responses to the manipulation check scales were examined with dependent samples *t*-tests to determine perceived task difficulty across conditions both before and after blocks of trials. Repeated measures analyses of variance (ANOVAs) were conducted across conditions of task difficulty for logarithmically transformed RTs to Navon letters and Flankers. Follow-up *t*-tests were conducted on RTs to the Navon letters to determine further differences between global and local elements across conditions.

A repeated measures one-way ANOVA was conducted across conditions of task difficulty for beta activity over the motor cortex. A 2 (Difficult vs. Easy) × 2 (Positive vs. Negative Feedback) repeated measures ANOVA was also conducted for reward positivity amplitudes. Follow-up *t*-tests were conducted on RewP amplitudes to determine further differences between positive and negative feedback conditions.

Suggested ranges of ± 2 for skewness and kurtosis (Field, 2009) were used to examine distribution normality. There were no variables outside this range in terms of skewness or kurtosis. There was some leptokurtic distribution for beta activity in the difficult condition (kurtosis = 3.6). This greater leptokurtosis represents the effects of motivation on beta activity that was expected based on enhanced motivational intensity (Gable et al., 2016b). Moreover, violations of kurtosis are not as impactful as levels of skewness (Tabachnick and Fidell, 2012). Thus, a repeated measures ANOVA was still used for these analyses. In regard to equality of variances for repeated measures ANOVA analyses, sphericity is automatically assumed to reflect equality of variances because there are only two levels of each variable (Field, 2016).

¹ To score the RewP where the outcome valence was maximal, a 2 (Difficult vs. Easy) × 2 (Sites Cz, CPz, and Pz) ANOVA on the positive–negative feedback difference scores revealed only a main effect for site, $F(1, 38) = 6.50$, $p < .003$, $\eta^2_p = 0.15$. Follow-up analyses revealed outcome valence was greater for Cz and CPz than Pz ($\rho_s < .003$). Outcome valence at Cz and CPz did not differ ($p > .22$).

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 ($M = 6.32$, $SD = 1.53$), $t(39) = -11.72$, $p < .000001$, $d = 1.86$. This means participants expected the difficult trials would be more difficult than the easy trials. Another dependent samples *t*-test revealed that participants felt they had performed more poorly after finishing the difficult blocks ($M = 3.29$, $SD = 1.63$) than the easy blocks ($M = 4.62$, $SD = 1.65$), $t(39) = -5.94$, $p < .00001$, $d = 0.94$. 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%. Although participant ratings of their perceived difficulty levels changed from the beginning to the end of the block (due to the manipulated feedback), they still thought difficult trials were more difficult relative to easy trials after the block was over. These manipulation checks suggest the manipulation produced the desired expectancy of task difficulty throughout the experiment.

Attentional narrowing and performance task

A 2 (Difficult vs. Easy) × 2 (Global vs. Local) repeated measures ANOVA revealed a significant interaction, $F(1, 38) = 5.27$, $p < .03$, $\eta^2_p = 0.12$ (see Fig. 2.A). Follow-up *t*-tests revealed RTs were faster to local targets in the difficult than in the easy condition, $t(38) = -2.98$, $p < .006$, $d = 0.52$, and faster to global than local targets in the easy condition, $t(38) = -2.40$, $p < .001$, $d = 0.65$. There were no differences between global and local RTs in the difficult condition and global RTs between the difficult and easy conditions ($\rho_s > 0.99$). 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. A repeated measures ANOVA revealed no significant difference in flanker RTs between the difficult and easy conditions, $F(1, 36) = 0.35$, $p > .55$. There was also no significant difference in flanker response accuracy between the difficult and easy conditions, $F(1, 36) = 2.71$, $p > .10$.

Beta suppression

A repeated measures analysis of variance (ANOVA) revealed beta suppression was greater during the difficult cues than easy cues, $F(1, 36) = 4.24$, $p < .05$, $\eta^2_p = 0.11$ (see Fig. 2.B). This suggests there was greater motor-action preparation during the difficult cues than during easy cues.

Reward positivity

A 2 (Difficult vs. Easy) × 2 (Positive vs. Negative Feedback) repeated measures ANOVA revealed a significant main effect for positive vs. negative feedback, $F(1, 38) = 105.01$, $p < .000001$, $\eta^2_p = 0.73$. There was also a trending interaction, $F(1, 38) = 3.30$, $p = .077$, $\eta^2_p = 0.08$ (see Fig. 2.C). Follow-up analyses revealed that RewP amplitudes were

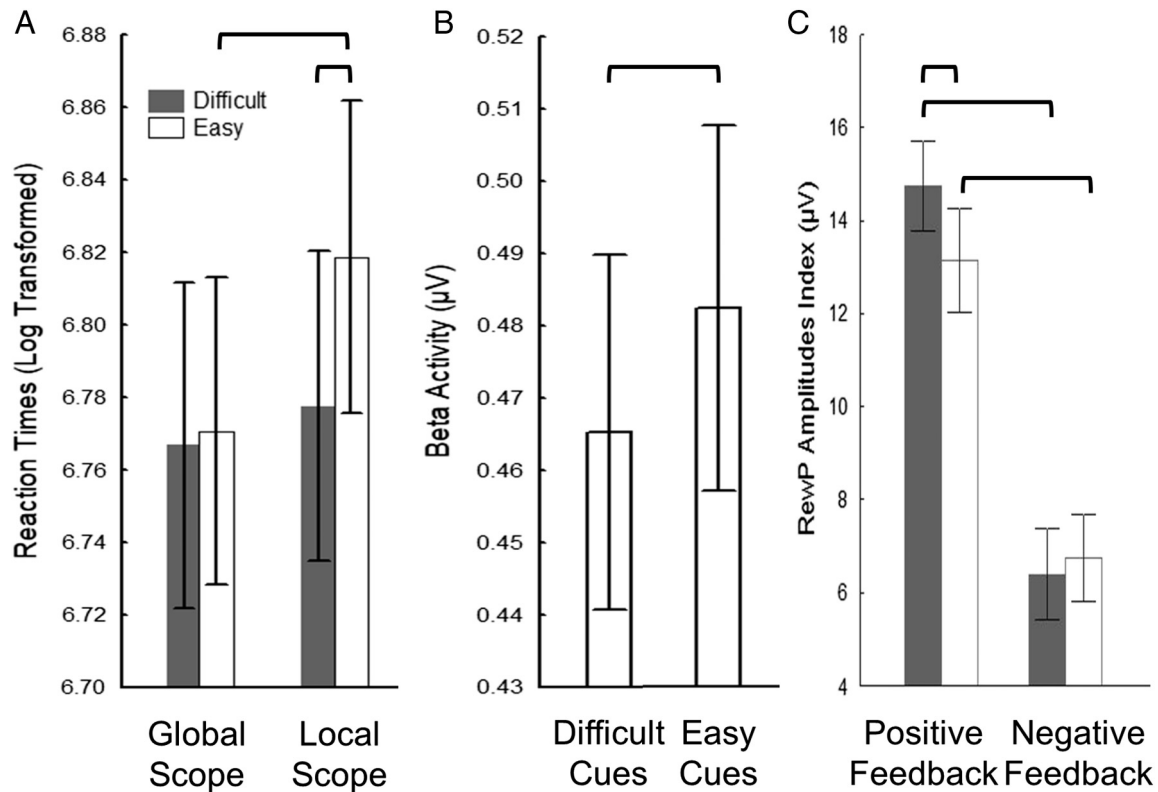


Fig. 2. All error bars indicate standard errors from the mean. All brackets indicate significant differences between conditions. **(A)** Navon letter reaction times to local and global targets in the easy and difficult conditions. **(B)** Beta activity over the motor cortex. Lower scores indicate greater beta suppression and motor-action preparation. **(C)** Reward Positivity amplitudes for site index (Cz and CPz).

significantly greater during difficult positive vs. easy positive feedback, $t(38) = 1.78$, $p < .05$, $d = 0.29$, greater for difficult positive vs. difficult negative feedback, $t(38) = 9.09$, $p < .000001$, $d = 1.46$, and greater for easy positive vs. easy negative feedback, $t(38) = 7.26$, $p < .000001$, $d = 1.16$. There was no difference between difficult negative and easy negative feedback ($p > .64$). See Fig. 3 for an illustration of the RewP waveforms and Fig. 4 for the average scalp topography.

DISCUSSION

The current study used performance expectancy based on a social comparison as a way to enhance intrinsic motivation (Wulf and Lewthwaite, 2016). Results revealed that manipulating intrinsic motivation by providing individuals with the expectancy of a difficult (vs. easy) task 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, manipulating the expectation that a task would be difficult caused a narrowed attentional scope, a cognitive consequence of high motivational intensity (Gable and Harmon-Jones, 2008). Results of the current study also show that greater perceived difficulty reduced 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 forming performance expectancies based on a social comparison has similar cognitive and neural consequences as enhancing extrinsic motivation.

The current findings that difficult (vs. easy) task expectancy enhances attentional narrowing are similar to previous work demonstrating that extrinsically motivated states high in motivational intensity states that narrow attentional scope (Gable and Harmon-Jones, 2008; Harmon-Jones et al., 2013a; Gable et al., 2016a; Gable et al., 2016b). Recently, some researchers have suggested that attentional changes occurring from intrinsically motivated states can contribute to performance and learning (Wulf and Lewthwaite, 2016). Our results build on this, suggesting that some types of intrinsic motivation (i.e., difficult task expectancy) focus attention on stimuli of interest. Perhaps the attentional narrowing resulting from enhanced intrinsic motivational states can enhance performance and learning (Bollinger et al., 2010; Shomstein and Johnson, 2013). Even though most of the research on attentional narrowing focuses predominantly on extrinsic motivational contexts, our findings shed more light on the importance of attentional narrowing in the larger scope of motivational research (whether intrinsic or extrinsic).

This study focused primarily on whether enhanced intrinsic motivation influenced cognitive and neural activity similarly to enhanced extrinsic motivation. However, the current study did not find differences in behavioral response times across conditions. This is likely due to flanker response demands

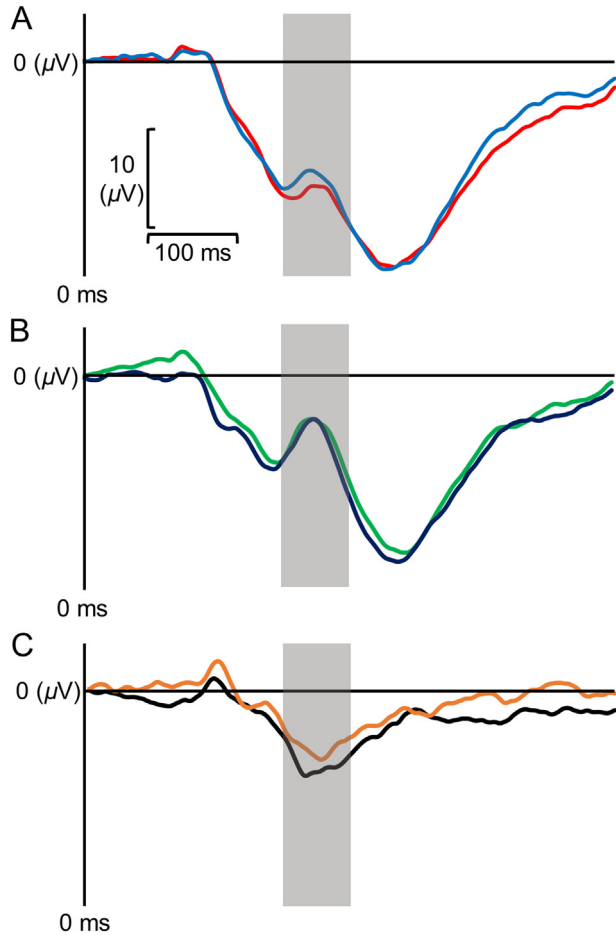


Fig. 3. RewP waveforms for wins in difficult and easy trials at the index for sites Cz and CPz. The gray bars represent the RewP time segments (220–300 ms). **(A)** RewP waveforms for positive feedback to difficult (red) vs. easy (blue) conditions. **(B)** RewP waveforms for negative feedback to difficult (green) vs. easy (blue) conditions. **(C)** RewP positive–negative feedback difference waveforms for difficult (black) vs. easy (orange) conditions. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

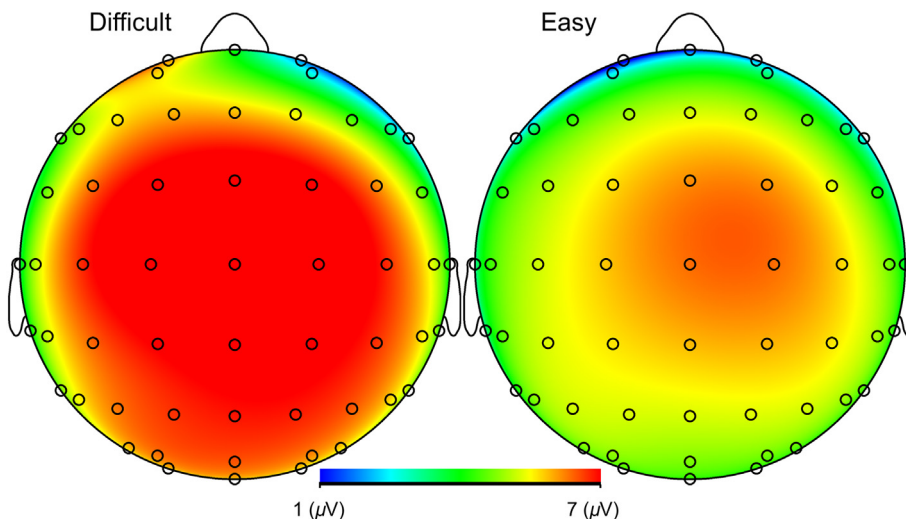


Fig. 4. Positive–negative feedback difference scalp topographies for RewP.

being low, and unlikely to be made much faster by the current manipulations (Huizinga et al., 2006). 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 additional task demands (e.g., time pressure) that would reduce response times (Behan et al., 2015; Dambacher and Hübner, 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 and Gable, 2018).

We also found reduced beta activity during trials with more perceived difficulty relative to easier trials. Prior studies on beta suppression and motivation strictly focused on monetary contexts, not intrinsically motivated states (Meyniel and Pesiglione, 2014; Meadows et al., 2016a; Gable et al., 2016b). The results in this study further expand this line of research by suggesting beta activity may be involved in the broader motivational context, instead of just extrinsically motivated states.

Literature on beta activation also suggests motor-action preparation is better directed towards goals of high value (Mirabella, 2014). In our study, manipulating difficulty of task expectancy also influenced beta activity. Beta activity was reduced when participants expected a task to be difficult (vs. easy). This suggests that intrinsic motivation enhanced by expectations of performance based social comparisons elicits better motor-action preparation. This interpretation is consistent with the idea that reduced beta activity reflects a phasic increase in dopamine (Kühn et al., 2008; Jenkinson and Brown, 2011), which is enhanced by rewards (Tobler et al., 2005).

Broadly, these results also provide evidence suggesting intrinsic motivation can influence the gating role of beta activity for future motor movement (van Wijk et al., 2012). This gating role is important for motor actions because beta activity seems to inhibit voluntary motor movements (Engel and Fries, 2010). This form of intrinsic motivation also seems to help with the gating role of beta activity, even though reduced beta activity may not necessarily mediate actual performance (Meadows et al., 2016a).

Finally, our results revealed that our participants also had greater RewP amplitudes for difficult wins vs. easy wins. This is consistent with past work on reward studies (Foti et al., 2011; Foti et al., 2015; Threadgill and Gable, 2016; Meadows et al., 2016b). Our findings also extend the study of intrinsic motivation by showing the similarity of feedback processing during intrinsic and extrinsic states. Greater RewP amplitudes for difficult wins may be reflecting the greater dopaminergic activity that enhances performance monitoring within an

intrinsic context as well (Holroyd and Coles, 2002; Carlson et al., 2011). This would suggest that intrinsic motivation acted as a multiplier on the expected reward. Reward-prediction may have been communicated to neural generators of the RewP in anterior cingulate through the midbrain dopamine system.

Taken together, our RewP results suggest that intrinsic motivators can also influence 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 and learning (Wulf and Lewthwaite, 2016). Because the RewP reflects performance monitoring, it may also be involved in the subsequent advantages of intrinsic motivation. For instance, recent work found RewP amplitudes to be similar between monetary and social feedback (Ait Oumeziane et al. (2017)).

One limitation of the current study is that enhanced motivation in the difficult task condition could be the result of two different factors. Presumably, participants could be motivated by social comparison expectancies (e.g., the opportunity to outperform their peers). The more difficult trials offered participants the opportunity to outperform their peers. Results demonstrated that participants did expect to do better than their peers on these trials, expecting to win 20–30% of the time on trials where their peers only won 10% of the time. On the other hand, participants could be motivated by the increased effort required to perform well in the difficult task (e.g., the need to put forth more effort to win). It is also possible that participants were motivated by both of these factors, as they are not mutually exclusive. In fact, both of these factors could be potentially additive; the need to exert effort in order to win plus the opportunity to do better than my peers increase intrinsic motivation. Regardless of the specific factor leading to increased motivation, the current studies demonstrate that social expectancy increased intrinsic motivation.

In sum, we found that intrinsic motivation, associated with difficult expectancy, narrowed attentional scope, enhanced cortical motor-action preparation, and increased neural feedback processing. These effects were comparable to that of extrinsic rewards (Threadgill and Gable, 2016; Gable et al., 2016a, 2016b). This study also supports the need for integrating some of the behavioral and phenomenological observations of intrinsic motivation with empirical physiological measures (Di Domenico and Ryan, 2017). Doing so can help us to understand both similarities and differences between intrinsic and extrinsic motivations more extensively by using a wider range of behavioral and physiological measures.

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