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The sweetness of successful goal pursuit: Approach-motivated pregoal states enhance the reward positivity during goal pursuit

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ABSTRACT

Traditionally, the reward positivity (RewP) is thought to index a binary performance monitoring system sensitive to approach motivation. However, recent theoretical models have argued that feedback processing extends beyond simple "good" vs. "bad" associations, such that performance monitoring incorporates the complex, multi-step sequence of behaviors often necessary to attain rewards. The present study sought to go beyond simple stimulus-response paradigms to examine how approach-motivated states occurring in multi-step goal pursuit impacts the RewP. Additionally, outcome frequency was varied to examine how the P3, a neural marker of expectancy, influences the RewP. Using a modified monetary incentive delay paradigm, participants played a reaction time game where multiple correct responses were required to attain a reward. Additionally, each trial had the potential for a reward (approach-motivated state) or no reward (neutral state). Results revealed that RewP amplitudes were larger after reward trial win feedback than after reward trial no-win feedback across multiple stages of goal pursuit. Additionally, after for controlling outcome frequency via the P3, RewP amplitudes were larger in reward trials than in neutral trials across incremental stages of goal pursuit. The RewP appears to be sensitive to feedback indicating successfully completing sub-goals during pursuit of a goal, even when no immediate reward is given. Approach motivation enhances performance monitoring when multiple steps are needed to attain a desired outcome, which may increase the likelihood of goal acquisition and attainment.

1. Introduction

Critical to the examination of goal pursuit is an understanding of feedback processing signaling the success or failure of actions during goal pursuit. Feedback processing reflects active performance monitoring and serves to inform individuals whether actions were successful or unsuccessful. However, recent research in performance monitoring have posited that feedback processing extends beyond simple "good" vs. "bad" associations, such that performance monitoring incorporates the complex environments in which much of human behavior exists (Holroyd and Yeung, 2012; Sambrook and Goslin, 2015). For example, successful goal accomplishment often requires a sequence of successful behaviors. Each successfully completed sub-goal is evaluated not just as an independent accomplishment, but also as a desired outcome that ultimately leads to an overall goal (Botvinick, 2008). That is, goal performance monitoring is more complex because goals are often the combination of a series of behaviors that ultimately leads to goal accomplishment.

This perspective is consistent with hierarchical reinforcement learning theory. Sequences in human behavior are broken down into simple subunits, with successful sequential actions bringing about a desired outcome. Neurally, dopaminergic activity in the basal ganglia, signaling the binary evaluation of feedback as good or bad, projects on to the anterior cingulate cortex to glean information useful for determining future behaviors (Holroyd and McClure, 2015). This communication between brain regions allows for the selection and maintenance of a sequence of simple behaviors in order to complete complex tasks and attain desired rewards.

Based on this idea, neurophysiological assessments of feedback processing likely reflect stepwise progression in goal pursuit. The reward positivity (RewP) is an ERP component thought to reflect the evaluation of performance feedback and action monitoring (Proudfit, 2015). Traditionally known as the feedback negativity, this ERP component is an underlying positive-going deflection occurring approximately 250 ms after performance feedback at frontocentral sites (Levinson et al., 2017). Positive feedback evokes a larger positive-going wave than negative or neutral feedback (Holroyd et al., 2006; Holroyd et al., 2011; Weinberg et al., 2014), suggesting that the RewP reflects

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the appraisal of external feedback as either positive or negative. Additionally, the RewP is sensitive to both outcome magnitude (Meadows et al., 2016) and likelihood (Sambrook and Goslin, 2015), in that high magnitude outcomes, as well as infrequent outcomes, elicit a larger RewP than low magnitude outcomes and frequent outcomes, respectively.

Research has suggested that the RewP may be driven by the mesocorticolimbic dopamine system, a neural network associated with reward processing (Carlson et al., 2011; Santesso et al., 2008). Source localization suggests the RewP may be generated from the anterior cingulate cortex (Gehring and Willoughby, 2002; Hauser et al., 2014; Holroyd and Coles, 2002), striatum, and medial prefrontal cortex (Foti et al., 2011; Carlson et al., 2011; Carlson et al., 2015). Because the RewP appears to be linked with the mesocorticolimbic dopamine system, the RewP may also be sensitive to approach-motivated states that drive an organism to attain a desired outcome (Depue and Collins, 1999).

Consistent with the premise that the RewP is related to approach motivation, traits associated with approach-motivation have been linked with the RewP. For example, greater trait approach motivation measured using Carver and White's (1994) Behavioral Activation Scale correlated with larger RewPs in gambling tasks (Lange et al., 2012). Larger RewPs have also been linked with measures of reward responsiveness (Bress and Hajcak, 2013), liking of desirable rewards (Angus et al., 2015), and degree of perceived agency in obtaining awards (Yeung et al., 2005). More recent work examining the influence of state approach motivation has found that high approach-motivated pregoal positive states evoke a larger RewP than neutral states (Threadgill and Gable, 2016). Larger RewPs in approach-motivated pregoal positive states relates to better performance (i.e., faster reaction times) on the goal-related task, suggesting that enhanced performance in approach motivated states enhanced rewarding feedback sensitivity. Furthermore, research has shown that as increases in potential monetary rewards enhance approach motivation, RewP amplitudes also increase (Meadows et al., 2016). In sum, the RewP appears to be strongly related to approach motivation, such that greater approach motivation enhances RewP amplitudes.

Approach-motivated goal states are multi-step processes comprised of multiple sub-goals in pursuit of the meta-goal (Corr, 2008; Corr and Cooper, 2016). Performance monitoring assessed by the RewP may be sensitive to approach motivation during progress towards a goal. For example, Osinsky et al. (2012) found that outcomes on the preceding trials had an impact on RewP amplitudes. If participants had won the two previous trials, they exhibited a smaller RewP than when they lost the two previous trials, suggesting that outcome history is used in evaluating the present outcome in pursuit of the meta-goal (i.e., winning as much money as possible). Research has also found that the RewP is largest when the instantaneous feedback in a trial is both positive and brings the organism closer to the receipt of the meta-goal (Osinsky et al., 2017). The RewP appears to index enhanced performance monitoring throughout approach-motivated goal pursuit. However, this past work raises the question: is the RewP sensitive to feedback indicating successfully completing sub-goals during movement towards a goal, even when no immediate reward is given?

1.1. The current study

The RewP is sensitive to approach motivation and appears to be sensitive to the stages of goal pursuit leading to goal accomplishment. In the current study, we sought to examine whether the RewP would be sensitive to approach motivation across multiple stages leading to goal accomplishment. To test this, we used a modified monetary incentive delay (MID) task to evoke either approach-motivated pregoal states or neutral states using either monetary incentives or no monetary incentive, respectively. The MID task has been found to elicit the dynamics of goal pursuit and attainment within the same participant within the same trial by having participants respond as quickly as possible to a target and then providing win or no-win feedback (Gable et al., 2016; Novak and Foti, 2015). In our modified MID task, participants had to win (respond quickly enough) to at least two targets in order to “win” each trial. That is, each trial required multiple steps (i.e., successful target responses) in order to reach an overarching goal of winning money on the trial.

Additionally, in the task, we varied successful or unsuccessful feedback frequency (expectancy). This allowed us to examine how outcome frequency impacts neural signatures of feedback processing within the same participant within the same trial. The RewP appears to be an indicator of performance outcome, but another ERP component known as the P3 is sensitive to outcome frequency (von Borries et al., 2013). The P3 occurs at centroparietal sites approximately 350–600 ms after feedback and is larger to infrequent, as opposed to frequent, stimuli (Duncan-Johnson and Donchin, 1977; Hajcak et al., 2005). Additionally, some research has found that the P3 is also sensitive to task-relevant information (i.e., valence feedback) and motivational context (Meadows et al., 2016; San Martín, 2012). Because of the close temporal relationship between the RewP and the P3, large P3 amplitudes evoked by infrequent feedback can influence the RewP (Holroyd et al., 2003; Novak and Foti, 2015). We will assess the RewP and P3 separately, as well as examine the influence of the P3 on RewP amplitudes.

When feedback frequency is the same, we predict that the RewP should be larger following win feedback than non-win feedback. We also predict that the RewP should be larger to win feedback in approach-motivated goal states than win feedback in neutral states. Furthermore, we predict that approach motivation should enhance the RewP to win feedback following both the first and second successfully completed task in a trial leading to successful goal attainment.

We predict that the P3 should be larger to infrequent outcomes than frequent outcomes, regardless of feedback type. Because frequency should modulate P3 amplitudes, P3 amplitudes may influence RewP amplitudes when feedback frequency varies. That is, when feedback frequency differs, we predict that RewP amplitudes may be sensitive to frequency because of the P3 influence. However, when controlling for variance in P3 amplitudes in RewP amplitudes, RewP amplitudes will not be sensitive to feedback frequency.

2. Methods

Fifty-six introductory psychology students participated in exchange for partial course credit. Informed consent was obtained prior to the experiment. Data were checked for outliers (greater than three standard deviations from the mean); all outliers were removed. Analyses with outliers removed are reported in the results; specifically, three outliers (greater than three standard deviations from the mean) were removed for the corrected RewP analyses. Participants were informed they would be playing a reaction time game in which they could win a total of $10.00, which would be converted to points and redeemable for different delicious desserts.

2.1. Procedures

Participants came into the lab and completed measures of handedness (Chapman and Chapman, 1987). All participants were right-handed. EEG electrodes were applied and tested for impedance. Participants then participated in a reaction time game designed to manipulate approach-motivated or neutral states using incentives or no-incentives, respectively. After all trials, participants were debriefed and given candy for their performance in the reaction time game.

2.2. Reaction time game

The reaction time game consisted of a modified monetary incentive delay paradigm. Each trial (n = 108; see Fig. 1) began with either a