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Effects of intrinsic motivation on feedback processing during learning

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ABSTRACT

Learning commonly requires feedback about the consequences of one's actions, which can drive learners to modify their behavior. Motivation may determine how sensitive an individual might be to such feedback, particularly in educational contexts where some students value academic achievement more than others. Thus, motivation for a task might influence the value placed on performance feedback and how effectively it is used to improve learning. To investigate the interplay between intrinsic motivation and feedback processing, we used functional magnetic resonance imaging (fMRI) during feedback-based learning before and after a novel manipulation based on motivational interviewing, a technique for enhancing treatment motivation in mental health settings. Because of its role in the reinforcement learning system, the striatum is situated to play a significant role in the modulation of learning based on motivation. Consistent with this idea, motivation levels during the task were associated with sensitivity to positive versus negative feedback in the striatum. Additionally, heightened motivation following a brief motivational interview was associated with increases in feedback sensitivity in the left medial temporal lobe. Our results suggest that motivation modulates neural responses to performance-related feedback, and furthermore that changes in motivation facilitate processing in areas that support learning and memory.

Performance-related feedback is an important part of effortful learning, as information about correct responses and errors can motivate learners to adapt their behaviors. Such feedback engages the striatum, widely regarded as a key region for processing reward-related information, even in the absence of extrinsically rewarding or punishing outcomes (e.g., Daniel and Pollmann, 2010; Satterthwaite et al., 2012; Tricomi et al., 2006). However, the affective experience of performance-related feedback may be more or less salient depending upon one's motivation to successfully complete the task. For example, positive performance feedback may be more reinforcing for a student who values scholastic achievement than for one who sees academics as irrelevant to his or her goals. As a result, it is likely that striatal engagement during feedback processing would be modulated by an individual's motivation to perform well.

The striatum serves a critical role in the reinforcement learning system, receiving input from midbrain dopamine neurons that convey information about unexpected rewards, and using information about rewarding consequences to learn to select adaptive behaviors (O'Doherty, 2004). Feedback-related responses in the striatum are presumed to reflect the affective value of positive and negative feedback in much the same way that reward responses reflect the subjective value of extrinsic rewards such as food or money (Satterthwaite et al., 2012). However, while previous research has established sensitivity to contextual influences in striatal responses to extrinsic rewards (e.g., Brosch et al., 2011; Chein et al., 2011; Delgado et al., 2008; Guitart-Masip et al., 2010; Nieuwenhuis et al., 2005), it is unclear how the learning context might influence the response of the striatum to positive and negative performance feedback. In particular, the motivation to perform well on a task may increase the affective salience of performance feedback, resulting in exaggerated striatal feedback responses.

Stable patterns of goal pursuit, assessed by trait measures of achievement goals, have been found to influence motivation and performance in experimental and academic situations (e.g., Grant and Dweck, 2003; Harackiewicz et al., 1997; Harackiewicz et al., 1998). Such traits have been linked with feedback-related activation in the striatum (e.g., DePasque Swanson and Tricomi, 2014); however, the relevance of a particular goal can also vary over time based on situational factors (Covington, 2000). For example, prior experimental work suggests that monetary rewards can enhance learning for boring material (Murayama and Kuhbandner, 2011). It is not always feasible or desirable to motivate academic performance or health behaviors with payments or other extrinsic rewards, which can potentially undermine intrinsic motivation for the desired behavior (Deci et al., 1999) or result in unintended negative long-term effects on future motivation (Gneezy et al., 2011); consequently, it is important to understand the effects of task-specific motivation on learning from feedback in the absence of extrinsic rewards or punishments. We aimed to increase the value of the learning goal itself, rather than using rewards that are extrinsic to the task to increase goal pursuit.

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Intrinsic motivation is characterized by a focus on the inherent satisfaction in performing a particular behavior for its own sake, in contrast with extrinsic motivation, in which the focus is on attaining some separable outcome (Ryan and Deci, 2000). Behavioral research suggests that a sense of autonomy, or being in control of one's choices, facilitates intrinsic motivation (Deci and Ryan, 1987). Because we sought to increase our participants' intrinsic motivation for our learning task, we required a manipulation that would support their autonomy at the same time as promoting reflection on the value of the task. Motivational interviewing is a strategy for enhancing motivation to change in substance abuse treatment and other health domains, which uses directive questioning to elicit "change talk," or self-generated statements in favor of pursuing treatment (Miller and Rollnick, 1991). In this regard, motivational interviewing supports autonomy to enhance intrinsic motivation.

Brief interventions based on the principles of motivational interviewing have demonstrated comparable efficacy to longer-term cognitive behavioral therapies for reducing substance abuse (Burke et al., 2003), but specific techniques used within motivational interviewing have rarely been tested experimentally. One notable exception is an fMRI study that found diminished neural responses to alcohol cues following self-generated change talk in alcohol dependent subjects, suggesting that motivational interviewing can promote the inhibition of maladaptive reward responses (Feldstein Ewing et al., 2011). Rather than diminishing the value of a maladaptive behavior, we aimed to use the principles of motivational interviewing to enhance motivation and performance on our learning task, by encouraging the participants to generate statements about the value of the learning task.

The aim of the present study was to investigate the effect of enhanced motivation on feedback processing during learning. To achieve this end, we performed two experiments. In the first, we tested a motivational interviewing manipulation that could increase motivation (or attenuate natural decreases in motivation) across two sessions of a learning task. In the second, we capitalized on the motivational variability within those who experienced the motivational interviewing manipulation and used fMRI to explore neural differences associated with varying motivation levels before and after the interview. In both experiments, participants completed two separate sessions of a feedback-based word association learning task. Changes in their motivation for each session were used to investigate motivational effects on learning and feedback processing.

General methods

To investigate how changes in intrinsic motivation for a learning task influence performance and neural responses to performance-related feedback during learning, we administered two independent sessions of a feedback-based learning task before and after a novel motivational manipulation. All procedures were approved by the Institutional Review Board of Rutgers University, and all participants gave written informed consent.

Materials and procedure

Experimental task

The participants completed two independent sessions of a word association learning task, adapted from a previous study of feedback processing in the striatum (Tricomi and Fiez, 2008; illustrated in Fig. 1). During this feedback-based learning task, the participants learned arbitrary word pairs through trial and error. Each trial required the participants to associate one main word with one of two other word choices, as in a multiple choice test with two response options. Since the words were semantically unrelated, learning was entirely dependent on the feedback that followed each response.

Eighty unique word pairs were learned during the first task session (BEFORE the motivational interviewing manipulation/control rest period), and eighty new pairs were learned during the second session (AFTER the manipulation/control rest period). Each session consisted of two learning phases with feedback, followed by a test phase without feedback, in which the same 80 word pairs were presented in random order, and the participants chose a match for the main word. During learning phase 1, the guesses as to the correct match for the top word were arbitrary, so the feedback during learning phase 1 was simply informative and did not reflect personal efficacy on the task. During learning phase 2, because the participants had previously been exposed to the correct word pairs, the feedback reflected the accuracy of the participants' memory in addition to providing information about the correct response. The word pairs tested BEFORE the motivational interviewing (MI) manipulation included only those pairs that were learned BEFORE the MI manipulation, and those tested AFTER the MI manipulation included only the 80 new word pairs that were introduced AFTER the MI manipulation.

Stimulus presentation and behavioral data collection were implemented with E-Prime software (Psychology Software Tools, Pittsburgh, PA). Each trial during the two learning phases began with a jittered fixation point (1–6 s), followed by the stimulus screen with the three words displayed (4 seconds), during which the participants choose one of the two response options, and concluded with the feedback screen (2 seconds) which displayed either a green checkmark (√) or a red "x." The self-paced test phase was nearly identical to the learning

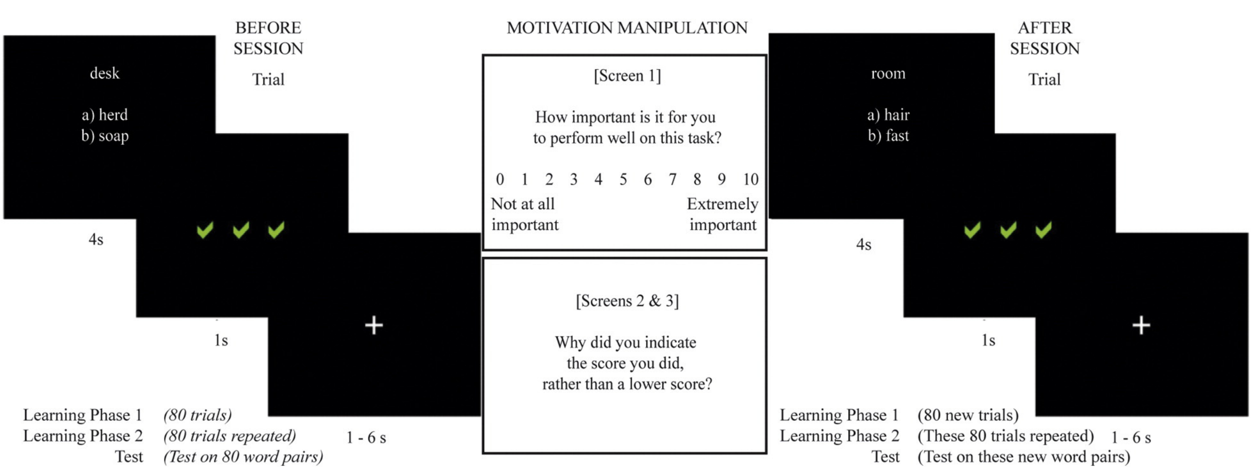

Fig. 1. Experimental design. Each participant completed a BEFORE and an AFTER learning session. Each trial required subjects to learn a word pair, with two opportunities to learn each word pair (learning phase 1 and learning hase 2) followed by a test phase. Each session contained 80 unique word pairs. The test phase for each learning session probed memory for only the word pairs that were learned during that session.