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Why self-controlled feedback enhances motor learning: Answers from electroencephalography and indices of motivation

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ABSTRACT

It was tested whether learners who choose when to receive augmented feedback while practicing a motor skill exhibit enhanced augmented feedback processing and intrinsic motivation, along with superior learning, relative to learners who do not control their feedback. Accordingly, participants were assigned to either self-control (Self) or yoked groups and asked to practice a non-dominant arm beanbag toss. Self participants received augmented feedback at their discretion, whereas Yoked participants were given feedback schedules matched to Self counterparts. Participants' visual feedback was occluded, and when they received augmented feedback, their processing of it was indexed with the electroencephalography-derived feedback-related negativity (FRN). Participants self-reported intrinsic motivation via the Intrinsic Motivation Inventory (IMI) after practice, and completed a retention and transfer test the next day to index learning. Results partially support the hypothesis. Specifically, Self participants reported higher IMI scores, exhibited larger FRNs, and demonstrated better accuracy on the transfer test, but not on the retention test, nor did they exhibit greater consistency on the retention or transfer tests. Additionally, post-hoc multiple regression analysis indicated FRN amplitude predicted transfer test accuracy (accounting for IMI score). Results suggest self-controlled feedback schedules enhance feedback processing, which enhances the transfer of a newly acquired motor skill.

1. Introduction

1.1. Self-controlled feedback

Developing protocols to enhance motor learning is crucial. One protocol whose effectiveness has been revealed in motor learning research is allowing learners control over their practice context (i.e., 'self-controlled practice'; see reviews by Sanli, Patterson, Bray, & Lee, 2013; Wulf, 2007). The most common way learners have been given control is by allowing them to

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choose when they receive augmented feedback (i.e., 'self-controlled feedback schedules'; Sanli et al., 2013). Indeed, the first self-controlled practice study manipulated control over feedback (Janelle, Kim, & Singer, 1995), and recent studies have done likewise (e.g., Chiviacowsky, 2014; Fairbrother, Laughlin, & Nguyen, 2012; Hansen, Pfeiffer, & Patterson, 2011). Generally, these studies have a self-control and yoked group, both of which attempt to learn a task. Self-control participants are given post-trial augmented feedback per their request during the acquisition phase, whereas each yoked participant is given a feedback schedule matched ('yoked') to his/her counterpart in the self-control group (this is unbeknownst to yoked participants, who believe they are simply given feedback at the experimenter's discretion). Self-control participants typically exhibit better learning than yoked participants during the retention and/or transfer test phase.

1.2. Self-controlled feedback and intrinsic motivation

Despite the number of studies reporting self-control participants exhibit superior motor learning, reasons for this result are largely speculative (Sanli et al., 2013). One speculation is self-control participants are more intrinsically motivated during the acquisition phase (Sanli et al., 2013; Wulf, 2007), and intrinsic motivation is associated with enhanced motor learning (Saemi, Wulf, Varzaneh, & Zarghami, 2011). Self-control participants are theorized to be more intrinsically motivated because they likely have higher perceived autonomy, which is positively associated with intrinsic motivation (Banack, Sabiston, & Bloom, 2011; Black & Deci, 2000; Jõesaar, Hein, & Hagger, 2012). This higher perceived autonomy is due to the freedom they are given in choosing their augmented feedback schedule (Su & Reeve, 2011). Another reason self-control participants are hypothesized to be more intrinsically motivated is because they have higher perceived competence (Chiviacowsky, 2014), which has been positively associated with intrinsic motivation (Standage, Duda, & Ntoumanis, 2003; Vallerand, Gauvin, & Halliwell, 1986; Vallerand & Reid, 1984). They have higher perceived competence because they generally receive positive feedback (Chiviacowsky, Wulf, & Lewthwaite, 2012), as they tend to request feedback primarily after good trials (Chiviacowsky & Wulf, 2002; Fairbrother et al., 2012). Yet, despite the rationale for why self-control participants should be more intrinsically motivated, empirical evidence is lacking (Sanli et al., 2013).

1.3. Self-controlled feedback and information (augmented feedback) processing

A second speculation why self-control participants exhibit superior motor learning is they engage in greater information processing during the acquisition phase (Sanli et al., 2013; Wulf, 2007). This could be reflected by greater augmented feedback processing. Specifically, self-control participants may process feedback more in depth than yoked participants. This is because self-control participants presumably request feedback when they believe it will be useful, whereas yoked participants receive feedback randomly. It could also be the case that self-control participants engage in greater augmented feedback processing because they are more intrinsically motivated to learn, and attempt to do so by utilizing augmented feedback to a greater extent. Regardless of why self-control participants may engage in greater augmented feedback processing, it is important to note that such processing is positively associated with motor learning (Luft, Nolte, & Bhattacharya, 2013; Luft, Takase, & Bhattacharya, 2014), but that empirical evidence that self-control participants engage in greater information (e.g., feedback) processing is lacking (Sanli et al., 2013).

1.4. Study purpose and design overview

Thus, the purpose of the present study was to test the hypothesis that self-control participants exhibit greater augmented feedback processing and are more intrinsically motivated than yoked participants. Accordingly, participants were assigned to either a self-control or yoked group and asked to practice a non-dominant arm beanbag toss to a target during the acquisition phase. Their visual feedback was occluded, and when they received augmented feedback, their processing of it was indexed with electroencephalography (EEG). Specifically, event-related potentials (ERPs) time-locked to feedback presentation were evaluated to assess processing. In particular, amplitude of the feedback-related negativity (FRN) component of the ERP waveform was measured. The FRN is a negative-going component that displays a frontocentral scalp distribution and peaks approximately 250–300 ms after feedback presentation (see Gehring, Liu, Orr, & Carp, 2012). Although the functionality of the FRN is debated, it is agreed the FRN reflects feedback processing, with more negative amplitudes indicating greater processing. Participants self-reported intrinsic motivation via the Intrinsic Motivation Inventory (IMI; McAuley, Duncan, & Tammen, 1989; Ryan, 1982) after acquisition, and completed a retention and transfer test the next day. During the transfer test, the target was closer to participants, thus requiring them to adjust the force of their tosses. Accordingly, this test indexed participants' ability to adapt the skill to new parameters. The transfer test was included because prior self-controlled feedback research employing a beanbag tossing paradigm revealed self-control and yoked groups exhibited performance differences on a transfer test in which the target is at a different distance than during acquisition, but exhibited no differences on a retention test (e.g., Fairbrother et al., 2012). Fairbrother et al. (2012) suggested this is because self-control participants are able to fine-tune the force of their tosses, since they choose to receive feedback after relatively accurate trials, whereas yoked participants more often receive feedback after inaccurate tosses requiring gross adjustments in force. As such, self-control participants become more adept at scaling the force of their tosses, which may be particularly beneficial when required to adjust force during a transfer test. Although this theory is reasonable, it has not been empirically validated.