Red or Blue: Does the choice of hue influence the way you learn the things you do?
A mechanistic account of the effects of incidental choice on motor learning.

by

Kirk Francis Grand

A dissertation submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Doctor of Philosophy

Auburn, Alabama
August 6, 2016

Keywords: motor learning; autonomy; motivation;
feedback processing; electroencephalography

Approved by

Mathew Miller, Chair, Assistant Professor of Kinesiology
Keith Lohse, Assistant Professor of Kinesiology
Jennifer Robinson, Associate Professor of Psychology
Mary Rudisill, Professor of Kinesiology

Abstract

The enhancement of motor learning is important for a myriad of activities. One way to enhance motor learning is to increase the autonomy of the learner. This can be done in several ways but typically centers around the learner having control over one or several variables of practice. The primary focus of Experiment 1 was to examine the effects of self-controlled feedback schedules on motor learning. Specifically, Experiment 1 was a mechanistic investigation of learners who were given choice (self participants) about when they received augmented feedback while practicing a non-dominant arm beanbag toss and the influence of the choice on information processing and motivation. Results showed that self participants exhibited superior motor learning, as measured by accuracy on a retention test. Additionally, self participants processed information to a greater extent (as indexed by electroencephalography [EEG]) and displayed greater intrinsic motivation (as indexed by the Intrinsic Motivation Inventory [IMI]). A post-hoc regression analysis revealed that information processing and motivation, as a set, predicted motor learning.

To further investigate the relationship a practice choice may have on skill acquisition a second experiment was performed. The primary purpose of the second study was to determine whether motivation and feedback processing explain the effect incidental choices (task-irrelevant choices) can have on motor learning. To this end, participants were assigned to one of two groups, choice or yoked, then asked to practice a non-dominant arm bean bag toss to a target. The choice group was allowed to choose the color of the beanbag with which they made the toss, whereas the yoked group had a color selected for them. Feedback processing and motivation were indexed via EEG and the IMI, respectively. Results show that an incidental choice failed to improve motor learning. Additionally, an incidental choice did not enhance motivation or feedback processing, neither of which predicted motor learning.

Acknowledgments

“Sometimes you never know the value of a moment until it becomes a memory.”
Dr. Seuss

Sometimes you don’t know the value of a person in your life until it transitions. You realize how important people have been on your journey to where you are, and where you plan to go. As I reflect on my journey I think about people I’ve met that have changed how I see the world. That is the beauty of meeting people and learning about them. It changes your lens on the world. It influences your journey. It challenges you. It helps you grow.

I am thankful for my entire committee. The knowledge and skills you have imparted to me are second to none!

I am forever thankful for Dr. Miller and Dr. Lohse for guiding me on my journey at Auburn, I have truly learned so much! I see the world differently having had the opportunity to get to know and work with you both!

A special thank you to Dr. Rudisill. You’ve had a tremendous influence on me as a scholar and a leader. You’ve also have had a huge influence on my growth as person, I am forever grateful!

Most importantly thank you to my family! The page isn’t long enough to express my love and gratitude. I wouldn’t be here or sane without you!

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List of Abbreviations

BVE	Bivariate Variable Error
ERN	Error-Related Negativity
EEG	Electroencephalogram/Electroencephalography
ERP	Event-Related Potential
FRN	Feedback-Related Negativity
IMI	Intrinsic Motivation Inventory
RE	Radial Error
RewP	Reward Positivity

Experiment 1

Published as Grand, K. F., Bruzi, A. T., Dyke, F. B., Godwin, M. M., Leiker, A. M., Thompson, A. G., Buchanan, T. L., & Miller, M. W. (2015). Why self-controlled feedback enhances motor learning: Answers from electroencephalography and indices of motivation. *Human Movement Science*, *43*, 23 – 32. doi: 10.1016/j.humov.2015.06.013.

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 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 (Vallerand, Gauvin, & Halliwell, 1986; Vallerand & Reid, 1984; Standage, Duda, & Ntoumanis, 2003). 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, Takse, & 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.

1.5. Hypotheses

It was predicted self-control participants would exhibit: (1) superior learning, as indicated by greater accuracy (lower radial error) and consistency (bivariate variable error) on the retention and/or transfer tests, but that radial error would be more sensitive to group differences, in accord with the extant literature (Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997); (2) more intrinsic motivation, as indicated by higher IMI scores; and (3) greater feedback processing, as reflected by more negative FRN amplitudes.

2. Methods

2.1. Participants

Thirty-six young adults completed the study (18 females). They were recruited by word-of-mouth and not compensated. They were quasi-randomly assigned to a self-control (self, n = 18) or yoked (n = 18) group in order to ensure that each male was yoked to a male, and each female to a female. The mean age of self participants was 23.9 years (*SD* = 4.35 years), and the mean age of yoked participants was 22.3 years (*SD* = 1.97 years). All participants were right-handed with the exception of one female in the self group, who threw with her non-dominant (right) arm and exhibited radial error and bivariate variable errors within 0.54 *SD*s of the mean across all participants. All participants provided informed written consent prior to the study, and none had experience with the experimental task or procedure[1].

2.2. Apparatus and Task

Participants executed underhand beanbag tosses with their non-dominant arm (as determined by the Edinburgh Handedness Inventory [Oldfield, 1971]) in order to hit the bull's eye of a circular target placed on the floor 300 cm away. The bull's eye had a radius of 10 cm,

[1] Eight participants (four in each group) did not have their EEG recorded/analyzed due to (a) being left-handed, (b) having hair that made EEG recording too difficult, (c) requesting feedback on too few trials (< 20) to obtain a reliable average of the FRN (Marco-Pallares, Cucurell, Münte, Strien, & Rodriguez-Fornells, 2011), or (d) having their yoked counterpart not have his/her EEG analyzed for one of the aforementioned reasons. A different eight participants (the first four in each group) did not have an intrinsic motivation score. This is because these participants completed a Likert-scaled motivation questionnaire containing only one question, which was chosen for brevity. During data collection, it was observed this questionnaire may have lacked sensitivity to differences in motivation (every participant was reporting the same level of motivation). Thus, it was replaced with a longer, but more sensitive (and validated) motivation inventory (i.e., the IMI).

and it was surrounded by eight concentric circles, each of which progressively increased in radius by 10 cm. The result of each toss was determined by measuring the distance from the x- and y-axes passing through the center of the bull's eye to the part of the beanbag closest to the respective axis. Radial error and bivariate variable error was derived from these results (see Section 2.4.1 for details). Participants sat in a chair and tossed the beanbag over a board (187 x 122.5 cm) that occluded their vision of the target. A table (73.5 cm high) sat between the participant and the board. A computer monitor (38.5 cm) sat on the table, 75 cm from the participant (see Figure 1 for photograph of apparatus and task).

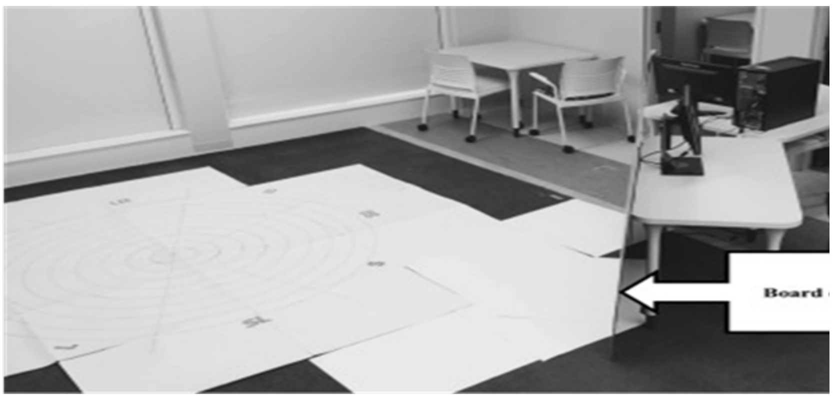

Figure 1. Pictorial description of experimental set-up.

2.3. Procedure

Upon arriving to the laboratory, participants were given an overview of the study procedures. Next, they were shown the legend used for augmented feedback to ensure they could discriminate the colors on the legend. Then, they completed a warm-up phase consisting of six trials of the task. All participants received augmented feedback after the first, second, fourth, and sixth warm-up trials. Participants then received a 3 min break before proceeding with the acquisition phase of the study. This phase consisted of ten blocks of six trials with 3 min breaks between each block. Participants were allowed to view the target prior to each block. The intertrial interval was approximately 30 s. Self participants were asked after every trial whether they wanted augmented feedback, whereas yoked participants were told after every trial whether they would receive augmented feedback (yoked participants' feedback schedules were yoked to their counterparts in the self group).

Augmented feedback was presented on the computer monitor as follows. First, a legend displaying a color spectrum consisting of 10 color steps was presented in the center of the monitor for 3000 ms. Each color step corresponded to how close a toss came to the bull's eye (e.g., red = bull's eye…dark blue = missed the target completely). For half of the participants in each group, 'warmer' colors indicated greater accuracy; for the other half of participants, 'cooler' colors indicated greater accuracy. After the legend disappeared, a fixation cross (+) appeared in its place for 3000 ms. Then a rectangle, the color of which corresponded to the accuracy of the previous toss, appeared just above the fixation cross for 1000 ms. After the augmented feedback disappeared from the monitor, auditory augmented feedback was provided. Specifically, an experimenter informed participants the direction in which their toss missed (long, long right, right, short right, short, short left, left, long left), unless it was a bull's eye, in which case "bull's eye" was stated. Feedback processing (EEG) was time-locked to the presentation of the colored rectangle. Although this feedback presentation only allowed participants' processing of the distance by which they missed the target (not the direction), it was preferable to presenting an image of the target with a marker indicating the precise location of the previous toss. This is because the latter presentation would have caused eye-movements to the marker, which could have corrupted EEG data (i.e., caused ocular artifact). Nonetheless, it is important to note the FRN only reflects processing of distance information in the present study.

After completing acquisition trials, participants completed a modified version of the IMI. Specifically, participants indicated the accuracy of statements about (1) interest/enjoyment while practicing the task, (2) perceived task competence, and (3) effort put into practicing the task as well as importance assigned to practicing the task. These subscales of the IMI were chosen as they contained questions most relevant for our study design (the subscales have also been employed in studies with similar designs [e.g., Badami, VaezMousavi, Wulf, & Namazizadeh, 2011]). The interest/enjoyment subscale consisted of seven statements, whereas the perceived competence and effort/importance subscales each contained five statements. Statement responses were made on a 7-point Likert scale and anchored as follows: 1 = not true at all, and 7 = very true. Internal consistency of each subscale and across subscales was high (Chronbach's α's ≥ .88). The subscales were averaged to create a composite measure of intrinsic motivation (Badami et al., 2011).

Approximately 24 h after completing acquisition, participants completed the retention and transfer tests. The task for the retention test was the same as acquisition, except no augmented feedback was provided. The retention test consisted of two blocks of six trials with a 3 min break. Participants were allowed to view the target prior to each block. The transfer test was the same as retention, except the bull's eye was 200 cm (as opposed to 300 cm) from participants.

2.4. Data Processing

2.4.1. Performance/Learning Data Processing

Radial error (accuracy) and bivariate variable error (consistency) were calculated as recommended by Hancock, Butler, and Fischman (1995): $Radial\ Error = (x^2 + y^2)^{1/2}$ and $Bivariate\ Variable\ Error = [(\frac{1}{k}) \sum_{i=1}^{k}[(x_i - x_c)^2 + (y_i - y_c)^2]\}^{1/2}$, where k = a given block of trials and $_c$ = centroid along the given axis (x or y).

2.4.2 EEG Recording and Signal Processing

Scalp EEG was collected from 28 channels of an EEG cap housing a 64 channel BrainVision actiCAP system (Brain Products GmbH, Munich, Germany) labeled in accord with an extended international 10-20 system (Oostenveld & Praamstra, 2001). EEG data were online-referenced to the left earlobe, and a common ground was employed at the FPz electrode site. Electrode impedances were maintained below 15 kΩ throughout the study and a high-pass filter was set at 0.016 Hz with a sampling rate of 1,000 Hz. The EEG signal was amplified and digitized with a BrainAmp DC amplifier (Brain Products GmbH) linked to BrainVision Recorder software (Brain Products GmbH).

EEG data processing was conducted with BrainVision Analyzer 2.0 software (BrainProducts GmbH, Munich, Germany). Data were re-referenced to an averaged ears montage, low-passed filtered at 20 Hz with a 48-dB rolloff employing a zero phase shift Butterworth filter. Next, the data were visually inspected for marked artifacts and then ocular artifacts were reduced employing the ICA-based ocular artifact rejection function within the BrainVision Analyzer software (electrode FP2 served as the VEOG channel). This function searches for an ocular artifact template in channel FP2, and then finds ICA-derived components that account for a user specified (70%) amount of variance in the template matched portion of the signal from FP2. These components were removed from the EEG signal, which was then reconstructed for further processing. ERPs were obtained by extracting the epoch of 200 ms prior to feedback (colored rectangle representing error distance) presentation through 800 ms post-feedback presentation, then baseline correcting with reference to the pre-feedback presentation interval. Next, each epoch was visually inspected and any epoch containing obvious artifact was excluded from subsequent analysis. The remaining epochs were then averaged. Each participant's average ERP was based on a minimum of 20 epochs. The FRN time window was determined by centering a narrow window around its peak as averaged across the Self and Yoked groups. This resulted in a time window of 275 – 305 ms. Next, mean amplitude was calculated at the electrode at which it was maximal (Fz).

2.5. Statistical Analysis

To assess group differences prior to acquisition, independent sample *t*-tests were conducted for radial error and bivariate variable error on the warm-up trials with group serving as the independent variable. To assess performance during acquisition, a 2 (Group) x 10 (Block) ANOVA was conducted with repeated measures on the second factor for both radial error and bivariate variable error. To assess learning, independent sample *t*-tests were conducted for the retention and transfer tests for both radial error and bivariate variable error with group serving as the independent variable. Error values for the retention test were derived by averaging across both retention test blocks, and values for the transfer test were derived by averaging across both transfer test blocks (blocks were averaged in order to provide a more stable index of test performance). The Greenhouse-Geisser correction is provided when sphericity was violated, and partial eta-squared (η^2_p) effect sizes are provided for ANOVAs with significant results. To assess intrinsic motivation, an independent sample *t*-test was conducted with group serving as the independent variable and IMI score as the dependent variable. To assess feedback processing, an independent sample *t*-test was conducted with group serving as the independent variable and FRN mean amplitude as the dependent variable. Cohen's *d* effect sizes are provided for *t*-tests with significant results. Alpha levels were set to .05 for all analyses.

3. Results

3.1. Warm-Up Trials

Independent sample *t*-tests revealed the groups were not significantly different during the warm-up trials with respect to radial error, $t(34) = 1.36$, $p = .18$ or bivariate variable error, $t(34) = 0.71$, $p = .48$.

3.2. Acquisition

Self participants requested feedback after 68.0 % (*SD* = 21.9 %) of trials during the first half of acquisition and 61.3 % (*SD* = 26.4 %) during the second half, thereby exhibiting a 'natural fading of feedback requests' (see Figure 2); however, a paired sample *t*-test revealed the difference in feedback requests per half was not significantly different ($p = .16$). A comparison of radial error on trials after which feedback was or was not received revealed the self group received feedback following more accurate trials (*M* = 28.4 cm *SD* = 10.2 cm) in comparison to trials after which they did not receive feedback (*M* = 40.6 cm, *SD* = 19.9 cm). This was not the case for the yoked group (feedback received: *M* = 33.0 cm, *SD* = 9.32 cm; feedback not received: *M* = 32.7 cm, *SD* = 9.32 cm). These group by feedback reception differences were statistically analyzed with a 2 (Group) x 2 (Feedback Reception [feedback received or not received]) ANOVA with repeated measures on the second factor and radial error serving as the dependent variable; and a significant interaction was revealed, $F(1, 26) = 5.85$, $p = .02$, $\eta^2_p = .18$. Fisher LSD post-hoc comparisons revealed a significant difference in the self group's radial error of trials after which feedback was or was not received ($p = .03$, $d = 0.77$), whereas no significant difference was observed for the yoked group ($p = .88$). Further post-hoc tests revealed the difference in radial error of trials after which self participants received feedback differed from those after which yoked participants received feedback at a level that approached conventional significance, $p = .09$, whereas the difference in radial error of trials after which the groups did not receive feedback did not approach a significant difference ($p = .20$).

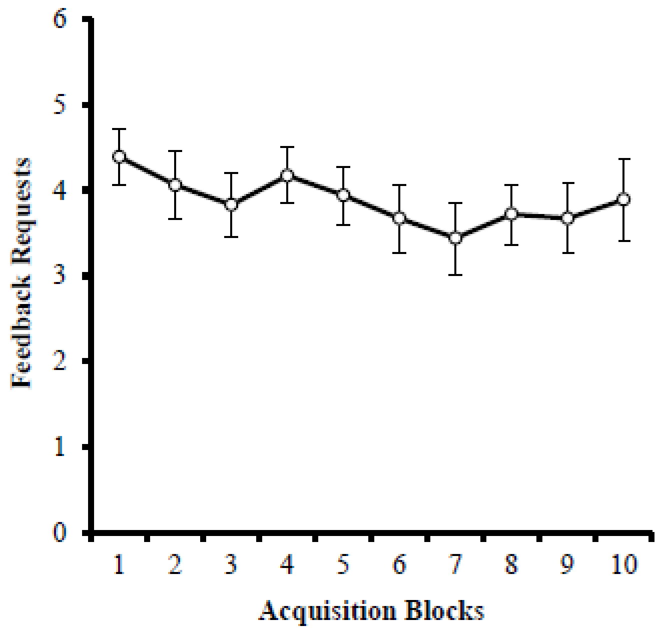

Figure 2. Self participants' feedback requests by block during acquisition phase.

Regarding radial error, a medium-sized main effect for block, $F(9, 306) = 2.48$, $p = .01$, $\eta^2_p = .07$, indicated accuracy increased over the course of acquisition (see Figure 3). No significant effects were observed for group or the Group x Block interaction ($F\text{s} \leq 1.03$). This suggests both groups performed the task equally well and with comparable degrees of increasing accuracy over the course of acquisition. Concerning bivariate variable error, no significant effects were observed for block, group, or the Group x Block interaction ($F\text{s} \leq 1$). This suggests neither group improved consistency over the course of acquisition, and the groups' consistency did not significantly differ during acquisition (see Figure 4).

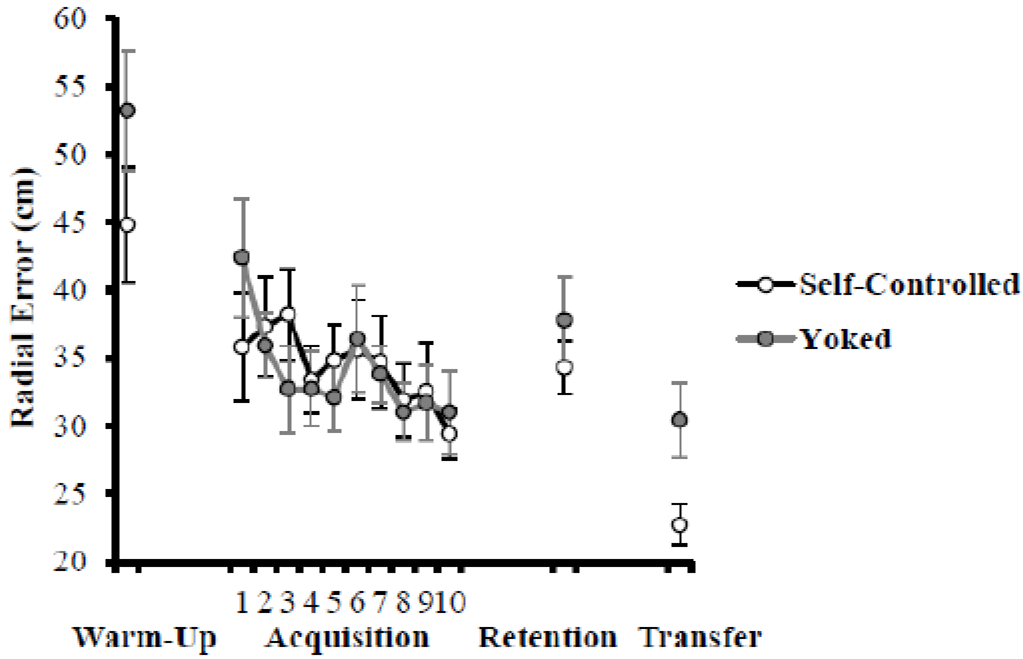

Figure 3. Accuracy (radial error) during warm-up, acquisition, retention, and transfer phases for self and yoked groups.

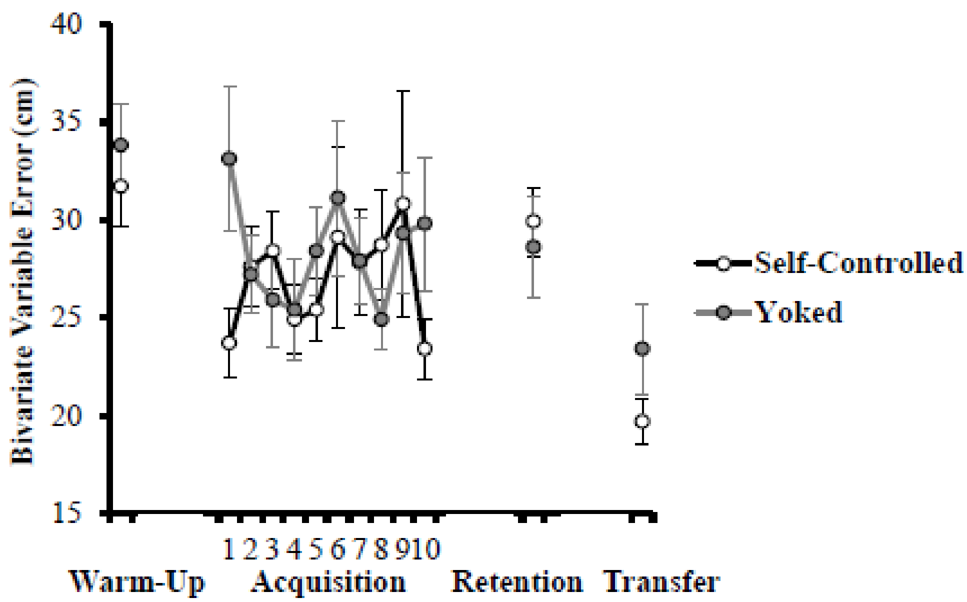

Figure 4. Consistency (bivariate variable error) during warm-up, acquisition, retention, and transfer phases for self and yoked groups.

3.3. Retention and Transfer

On the retention test, the groups did not significantly differ with respect to radial error, $t(34) = 0.93$, $p = .36$, or bivariate variable error, $t(34) = 0.40$, $p = .69$, indicating the groups exhibited similar degrees of accuracy and consistency on this test of learning. On the transfer test, the self group exhibited lower radial error ($M = 22.7$ cm, $SD = 6.23$ cm) than the yoked group ($M = 30.4$ cm, $SD = 11.7$ cm), $t\ (34) = 2.43$, $p = .02$, $d = 0.82$, revealing the former to be more accurate on this test of learning. The groups did not significantly differ with respect to bivariate variable error on the transfer test, $t(34) = 1.45$, $p = .16$, indicating they exhibited similar degrees of consistency on this test of learning. Since the transfer test involved a closer target than the retention test, it is possible the self group performed better on this test because they were undershooting on the retention test, which could have corresponded to greater accuracy on the transfer test. To determine whether this was the case, constant (signed) y-error (vertical bias) for the retention and transfer tests was assessed. The self group undershot to a *lesser* degree in the retention test ($M = -10.1$ cm, $SD = 13.6$ cm) than the yoked group ($M = -15.4$ cm, $SD = 21.5$). The self group overshot to a lesser degree in the transfer test ($M = 2.49$ cm, $SD = 12.5$ cm) than the yoked group ($M = 2.99$ cm, $SD = 18.9$). Independent sample *t*-tests with group serving as the independent variable and constant y-error serving as the dependent variable revealed these group differences were not significant (ps $\geq .39$). These results suggest the self group did not perform better on the transfer test because they were undershooting on the retention test.

3.4. IMI Score

The self group ($M = 5.39$, $SD = 0.70$) had a higher IMI score than the yoked group ($M = 4.70$, $SD = 0.92$), $t\ (26) = 2.21$, $p = .04$, $d = 0.85$. This suggests self participants were more intrinsically motivated when practicing the task. Subcomponent analysis revealed self participants reported numerically higher IMI scores on the interest/enjoyment subscale (*M* = 5.83 [*SD* = 0.71] vs. *M* = 5.1 [*SD* = 1.3]), perceived competence subscale (*M* = 4.36 [*SD* = 1.08] vs. *M* = 3.79 [*SD* = 0.79]), and effort/importance subscale (*M* = 5.97 [*SD* = 1.04] vs. *M* = 5.21 [*SD* = 1.18]), but these differences only approached conventional significance (*p*s = .08 - .12).

3.5. FRN Mean Amplitude

Figure 5 displays grand average ERPs for self and yoked groups at the Fz, Cz, and Pz electrodes, and the FRN is indicated at Fz, where it was maximal. The FRN is evident at all three electrodes, but it was only assessed at the electrode at which it was maximal, in order to avoid excessive statistical tests (Luck, 2014). Figure 6 displays FRN topographies for self and yoked groups. The topographies are similar to those of the FRN reported in studies employing feedback stimuli (see Gehring et al., 2012), suggesting the component identified in Figure 5 is indeed the FRN. Figure 5 reveals that, as hypothesized, FRN mean amplitude is larger (more negative) for the self group (*M* = 1.16, *SD* = 4.90) than the yoked group (*M* = 4.94, *SD* = 3.83), t (26) = 2.28), $p = .03$, $d = 0.87$. This suggests self participants processed augmented feedback to a greater extent while practicing the task. Although FRN mean amplitude differs between the two groups, it is possible this difference is driven by changes in an ERP component other than the FRN (see Luck, 2014). However, the component driving the difference is related to feedback processing, as the ERPs are time-locked to the onset of feedback stimuli. At the very least, it can be concluded the two groups differ in their feedback processing, regardless of whether this difference is being driven by the FRN. Notably, the difference in FRN amplitude is unlikely related to the degree of error represented by the feedback. This is because the yoked group received feedback after trials with larger errors (although this difference only approached conventional significance [$p = .09$]), and feedback indicating larger errors elicits greater FRN amplitudes (Luft et al., 2014). Thus, if FRN amplitude was being driven by the degree of error represented by the feedback, then the yoked group would exhibit a larger FRN amplitude.

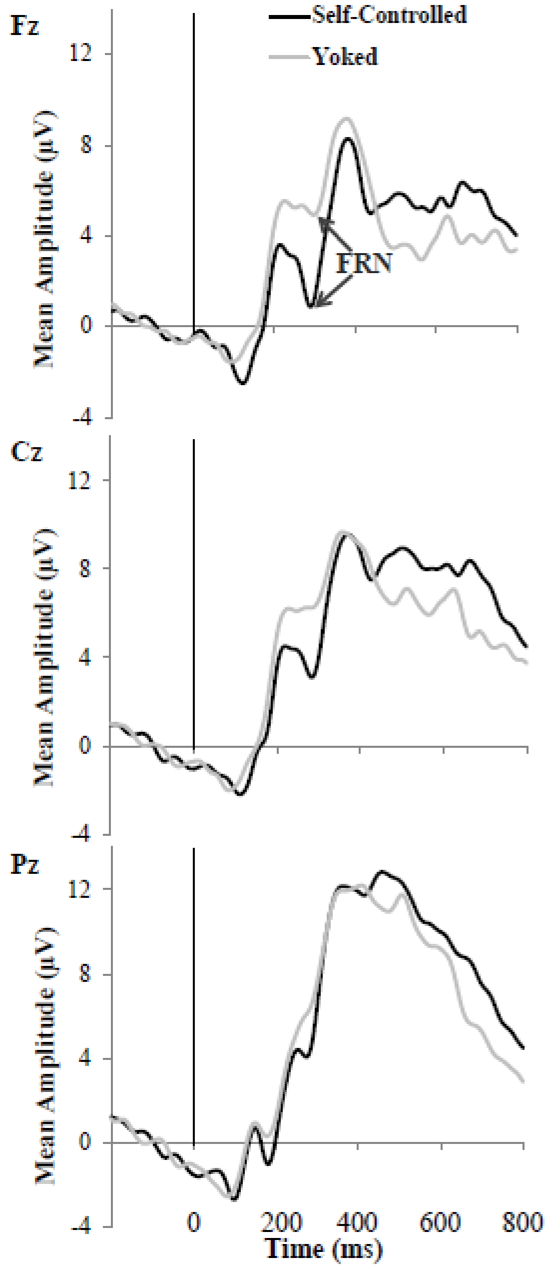

Figure 5. Grand average ERPs for self and yoked groups. As hypothesized, FRN mean amplitude is larger (more negative) for the self group, suggesting self participants processed augmented feedback to a greater extent while practicing the task.

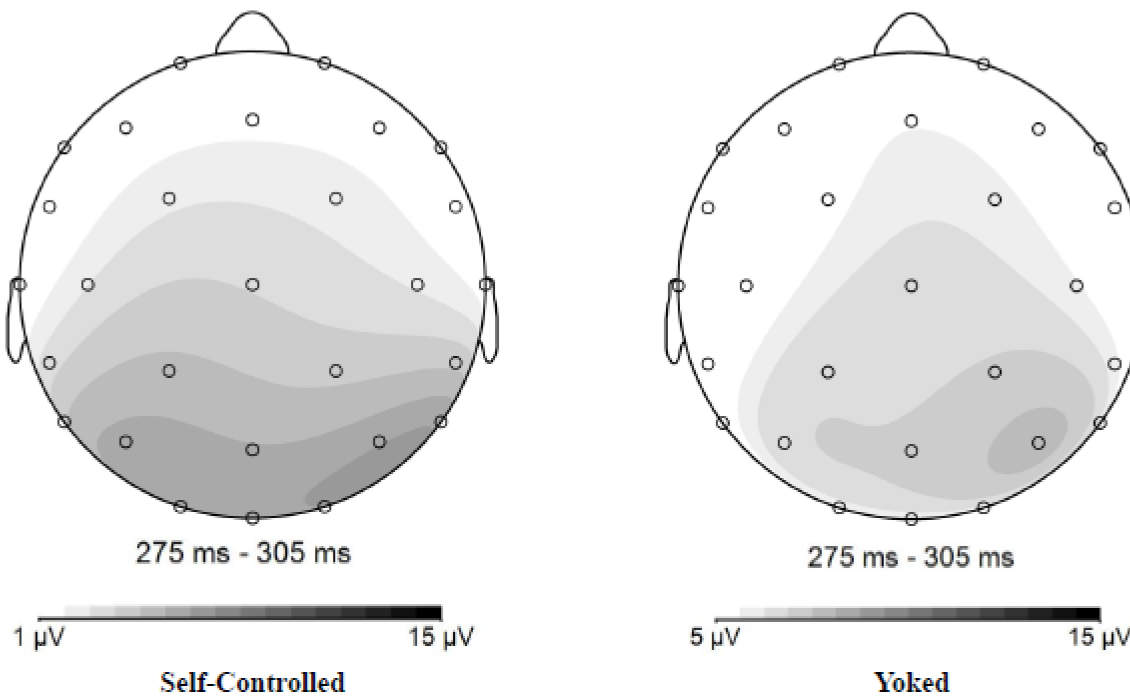

Figure 6. FRN topographies for self and yoked groups. The topographies are similar to those of the FRN reported in studies employing feedback stimuli, suggesting the component identified in Figure 5 is indeed the FRN.

3.6. Post-Hoc Regression Results

To assess the relationship between intrinsic motivation as well as feedback processing with motor learning, a regression analysis was conducted to explore whether intrinsic motivation and augmented feedback processing predicted transfer test radial error (the learning measure differentiating the self and yoked groups); this analysis was only performed for participants who had both predictors measured. Specifically, a stepwise hierarchical regression was conducted with standardized IMI score and standardized FRN mean amplitude serving as the independent variables in the first step, and the interaction between the two being added in the second step. Standardized values were employed in attempt to prevent the problem of high multicollinearity that can occur between first-order terms and the interaction term (Jaccard & Turrisi, 2003). The regression outlier diagnostics recommended by Cohen, Cohen, West, and Aiken (2003) revealed one outlier due to extremity on the independent variable (centered leverage > 3*k* / *n*) and two due to extremity from the regression line (externally studentized residual > 3.0). The first step of the regression indicated standardized IMI score and FRN mean amplitude, as a set, predicted transfer test radial error, F (2, 14) = 8.50, $p > .01$, $R^2 = .55$, and the second step failed to explain any additional variance, change in F ($p = .54$; see Figure 7). The standardized coefficients for the independent variables in the first step were as follows: standardized IMI score β = -.37, $p = .06$ and standardized FRN mean amplitude β = .69, $p = .01$[2]. These results suggest intrinsic motivation and augmented feedback processing, as a set, explained 54.8% of the variance in transfer test accuracy. When considering each predictor (while accounting for the other predictor), only FRN mean amplitude was a significant predictor of transfer test accuracy. Intrinsic motivation and feedback processing were not significantly correlated ($r = .14$, $p = .6$).

[2] To determine whether group assignment significantly affected these results, a second hierarchical regression was conducted with Group serving as the independent variable in the first step, standardized IMI score and standardized FRN mean amplitude being added in the second step, and the interaction between the two being added in the third step. This regression revealed the first step approached conventional significance in predicting transfer test accuracy ($p = .09$), and the second step added a significant proportion of explained variance, change in F ($p = .02$), but the third step did not add a significant proportion of explained variance, change in F ($p = .55$). Thus, group assignment did not significantly affect the results (e.g., reduce the predictive value added by IMI score and FRN mean amplitude).

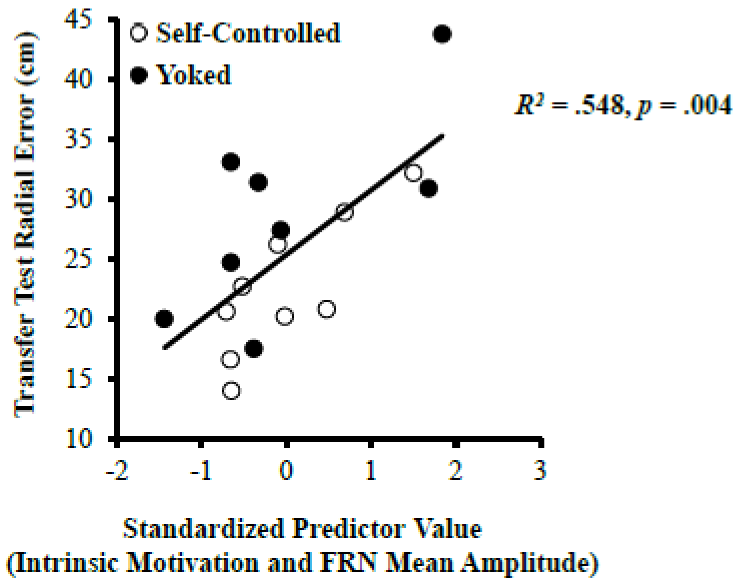

Figure 7. Multiple regression results revealing intrinsic motivation and FRN mean amplitude, as a set, predict transfer test accuracy (radial error). Data points are separated based on group.

4. Discussion

The purpose of the present study was to test the hypothesis that self-control participants exhibit greater intrinsic motivation and augmented feedback processing than yoked participants. self participants reported higher IMI scores, exhibited more negative FRN amplitudes, and demonstrated greater accuracy on a transfer test. No group differences in accuracy were observed during the acquisition or retention phases of the study nor were any group differences in consistency observed during any phase of the study. These results are fairly consistent with extant literature (Fairbrother, & Barros, 2011; Fairbrother et al., 2012; Janelle et al., 1997; Janelle et al., 1995). Post-hoc multiple regression analysis indicated IMI score and FRN amplitude, as a set, predicted transfer test accuracy. However, it should be noted that FRN amplitude was a stronger and more reliable predictor (in terms of β- and *p*-values) than IMI score, which was a relatively unreliable predictor in that its *p*-value only approached conventional significance in the model. Regardless, to our knowledge, this is the first study to report intrinsic motivation and augmented feedback processing, when considered together, predict a measure of motor learning. One other study showed evidence that intrinsic motivation predicted motor learning (Saemi et al., 2011), but this study did not consider augmented feedback processing; and two other studies showed evidence augmented feedback processing predicted motor learning (Luft et al., 2013; Luft et al., 2014), but these studies did not consider intrinsic motivation. Interestingly, intrinsic motivation and augmented feedback processing were not significantly correlated, suggesting that individuals who are more intrinsically motivated to learn do not necessarily engage in greater augmented feedback processing while learning. However, it is important to note the study was not designed for correlation/regression analyses and, thus, was severely underpowered for such tests. Therefore, results of such tests, including the fact that IMI score failed to reach conventional significance as an individual predictor in the model, should be considered in light of this limitation.

In addition to the underpowered correlational tests, a couple of other limitations should be noted. First, the experimental paradigm exaggerated the importance of augmented feedback to motor learning. This is because learners were compelled to rely heavily on augmented feedback due to the minimization of intrinsic feedback (occluding vision of the target), which is more accessible in most motor learning situations. Second, the only measure of motor learning on which self-control participants outperformed yoked participants was on transfer test accuracy. Interestingly, this result replicates that of Fairbrother et al. (2012), who employed nearly an identical paradigm. Thus, the present results support Fairbrother et al.'s assertion that transfer tests may more sensitive to motor learning differences between self-control and yoked participants. Additionally, the results provide modest support for Fairbrother et al.'s explanation for why the transfer test is more sensitive. Specifically, Fairbrother et al. suggested self-control participants receive feedback after better trials than yoked participants, allowing the former to become more adept at scaling the force of their tosses, which may be particularly beneficial when required to adjust force during a transfer test. Accordingly, the radial errors of trials after which self-control participants receive feedback should be lower than that of yoked participants; the present results revealed this difference approached conventional significance.

Despite its limitations, the present study provides several interesting results. In particular, the novel observation that intrinsic motivation and augmented feedback processing, as set, predict motor learning warrants future examination. If future studies reveal intrinsic motivation, as an individual predictor, reliably predicts motor learning, protocols to enhance intrinsic motivation during practice should receive further investigation. To this point, self-determination theory posits increasing perceptions of autonomy, competence, and relatedness should enhance intrinsic motivation (Deci & Ryan, 1985). Accordingly, one reason self-controlled feedback schedules may be so successful in enhancing motor learning is they increase perceptions of autonomy and competence. Other protocols to enhance intrinsic motivation could involve increasing perceived autonomy by giving learners choices over practice components besides feedback (e.g. schedule, difficulty, demonstrations); increasing perceived competence by providing augmented feedback after primarily good trials; and enhancing relatedness by having learners engage in cooperative practice.

If future studies reveal the processing of augmented feedback predicts motor learning, protocols to enhance feedback processing during practice deserve additional examination. To this point, it has recently been posited augmented feedback processing is sensitive to the feedback's perceived utility (Arbel, Goforth, & Donchin, 2013; Arbel, Murphy, & Donchin, 2014).

Accordingly, another reason self-controlled feedback schedules may be successful in enhancing motor learning is because learners are given feedback when they believe it will be useful. Besides providing learners control over feedback scheduling, instructors may be able to enhance learners' feedback processing by emphasizing the feedback's utility. Conversely, increasing learners' intrinsic motivation may not enhance feedback processing, given the weak correlation between the two variables observed in the present study. Accordingly, it may be prudent for instructors to develop strategies to enhance feedback processing, via self-controlled feedback, if their objective is to enhance the generalization of a newly acquired skill.

Experiment 2

1. Introduction

1.1. Incidental Choices and Motor Learning

Motor learning has important implications in many arenas, from athletics to the fine movements of a surgeon. Thus, determining ways to enhance motor learning is crucial. One method of enhancement is the manipulation of autonomy (Legault & Inzlicht, 2012; Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015; Sanli et al., 2013; Wulf, Chiviacowsky, & Cardozo, 2014). While there are many ways to manipulate autonomy (e.g., delivery of feedback, augmented task information, assistive devices, movement demonstrations), one method receiving attention recently is offering learners an incidental choice (Lewthwaite et al., 2015, Murayama, Matsumoto, Izuma, Sugiura et al., 2015). An incidental choice is defined as having autonomy over a task-irrelevant variable (e.g., choosing the color of a golf ball before a putt). Generally, in these studies one group is given a choice over some irrelevant aspect of the task and their performance is compared to a group not given an incidental choice during the task. The choice group typically exhibits superior learning, as measured by delayed retention tests.

1.2. Incidental Choices and Motivation

Despite studies reporting that incidental choices enhance motor learning, the mechanisms underlying the enhancement are unclear. One speculation is directly related to motivational influences, noting that participants who are given control over a variable involved in practice conditions are in a general sense more motivated to learn the task (Chiviacowsky et al., 2012). Motivation can be defined as a psychological property promoting action towards a goal by eliciting and/or sustaining goal directed behavior (based on Mogenson, Jones, & Yim, 1980; Wise, 2004). Offering a choice fulfills the desire to experience a sense of agency or to be in control of one's life circumstances, which has been recognized as a fundamental need (e.g. Deci & Ryan, 2000, 2008; Leotti, Iyengar, & Ochsner, 2010; Leotti & Delgado, 2011). Fulfilling this sense of control has been linked to increases in motivation, engagement (Leotti & Delgado, 2014), and performance (Cordova & Lepper, 1996; Tafarodi, Milne, & Smith, 1999).

Ample research has been conducted on the role of motivation in learning. One highly researched area uses monetary rewards (an external motivator), given during practice, to investigate the potential improvement in retention of learned motor sequences (Abe, Schambra, Wassermann, Luckenbaugh et al., 2011) and memory for visually presented stimuli (Adcock, Thangavel, Whitfield-Gabrieli, Knutson et al., 2006; Wittmann, Schott, Guderian, Frey et al., 2005; Wolosin, Zeithamova, & Preston, 2012). In a related line of research, the participants' inherent curiosity for certain topics (an intrinsic motivator) has been shown to regulate the strength of specific memories (Gruber, Gelman, & Ranganath, 2014; Kang, Hsu, Krajbich, Loewenstein et al., 2009). Similarly, studies have revealed that enriched learning environments enhance engagement with a task during practice, and more engaging environments during acquisition are associated with enhanced motor learning (Lohse, Boyd, & Hodges, 2016).

1.3. Incidental Choices and Information Processing

Another reason that incidental choices have been proposed to enhance learning involves increased information processing. By offering the participants an incidental choice, it may lessen needs for minor defensive, resistive, or anxious activation, which may allow for increased task-specific activity, and potentially greater information processing (Lewthwaite et al., 2015). One way offering an incidental choice may facilitate information processing involves the processing of augmented feedback. When an incidental choice is afforded, people are more likely to treat feedback as useful information for improving their own future, as opposed to assigning negative/positive affect to the feedback. This may distract from the information presented, thus reducing its utility on upcoming movements. This ability to process feedback agnostic to any affective content is referred to as interpreting feedback *informationally* (Ryan 1982, Deci and Ryan, 1985).

A proposed neurophysiological mechanism for the reduction of affective reactions and increased information processing of feedback involves the ventromedial prefrontal cortex (vmPFC). Previous studies have indicated the flexible role of both the striatum and the vmPFC (as well as the adjacent subgenual anterior cingulate cortex [ACC]) in the way they are influenced by various factors such as inter-temporal choice (Kable and Glimcher, 2007; Sellitto, Ciaramelli, & Pellegrino, 2010), social norms (Koenigs, Young, Adolphs, Tranel et al., 2007; Izuma, Saito, & Sadato, 2008), and emotion regulation (Delgado, Nearing, LeDoux, & Phelps, 2008; Wager, Davidson, Hughes, & Lindquist, 2008). Functional magnetic resonance imaging (fMRI) data has shown that failure feedback, compared with success feedback, elicited a drop in vmPFC activation in a forced choice condition, but not in a condition where the participants were given an incidental choice (Murayama et al., 2015). Thus, the administration of an incidental choice appears to increase informational processing of feedback, which could be a critical mechanism underlying the facilitative effect of an incidental choice on learning.

An electroencephalographic (EEG) component that is generated in a region just adjacent to the vmPFC, the ACC, is the error-related negativity (ERN). The ERN is elicited by intrinsic feedback about an error. The ERN has been implicated in cognitive control functions that enable the brain to adapt behavior to changing task demands and environmental circumstances (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Ridderinkof, 2004). Another view of the ERN suggests that, rather than simply reflecting attention to errors or discrepancies between desired and actual responses, the ERN is in fact linked to motivational and affective responses to such errors (Bartholow, Henry, Lust, Saults, & Wood, 2012; Inzlicht & Al-khindi, 2012; Luu, Collins, & Tucker, 2000). This perspective asserts that ERN amplitude is associated with the value placed on errors and that increased motivation will amplify the ERN (Weinberg, Reisel, & Hajcak, 2011). Expanding the motivational view, autonomous motivation is expected to enhance the degree to which performance is monitored and improved. Specifically, autonomy should promote acceptance, rather than suppression, of feedback information and its affective content, thereby enhancing performance monitoring and improvement. Indeed, similar to the effect an incidental choice has on buffering the reduction in vmPFC activation, autonomy support has been revealed to elicit a more negative ERN amplitude (i.e., greater error information processing) following failure feedback, as compared to failure feedback with no autonomy support (Legault & Inzlicht, 2013). This greater information processing indicates autonomy support facilitates performance monitoring, which should enhance learning.

1.4. Past and Present Study

Whereas the ERN reflects error processing based on intrinsic feedback, the feedback-related negativity (FRN) reflects error processing based on extrinsic feedback. The FRN is a negative-going component that displays a frontocentral scalp distribution and peaks approximately 250 – 300 ms after feedback presentation (Gehring, Liu, Orr, & Carp, 2012). Sometimes, however, the FRN is not evident because of the superimposition of frontocentral positive-going activity in the FRN time window (Baker & Holroyd, 2011; Holroyd, Pakzad-Vaezi, & Krigolson, 2008). The positive activity is known as the reward positivity (RewP). Notably, the FRN/RewP are believed to reflect phasic changes in dopaminergic signaling (Foti, Weinberg, Bernat, & Proudfit, 2015; Foti, Weinberg, Dien, & Hajcak, 2011), and modulations in dopaminergic signaling have been hypothesized to explain motivational effects in motor learning (see Wulf & Lewthwaite, 2016). Therefore, it is possible that providing autonomous motivation elicits larger FRN/RewP amplitudes and increases motor learning via modulating dopaminergic signaling.

Grand et al. (2015) used a self-controlled feedback schedule to manipulate autonomy. Results revealed the autonomy-support group exhibited more negative FRN amplitudes (i.e., greater information processing) in response to augmented feedback during motor skill acquisition (practice), when compared to a group with no autonomy but the same augmented feedback schedule (yoked group). Additionally, the autonomy support group exhibited increased intrinsic motivation scores via the Intrinsic Motivation Inventory (IMI; McAuley, Duncan, & Tammen, 1989) after acquisition. Notably, FRN amplitude and IMI score, as a set, predicted motor learning.

The primary purpose of the present study was to determine whether motivation and information (feedback) processing explain the effect incidental choices have on motor learning. To investigate this, participants were assigned to one of two groups, choice or yoked, then asked to practice a non-dominant arm bean bag toss to a target. The choice group was allowed to choose the color of the bean bag they made the toss with, while the yoked group had a color selected for them. Their visual feedback of the toss was occluded, but participants received augmented feedback, and their processing of it was indexed with EEG. Specifically, event-related potentials (ERPs) time-locked to feedback presentation were assessed. In particular, the amplitude of the FRN/RewP was quantified. Participants self-reported intrinsic, internalized, and general motivation via the IMI after acquisition and completed a retention and transfer test a week later to asses learning. Performance was measured using radial error (RE) and bivariate variable error BVE, which index accuracy and precision, respectively (Hancock, Butler, & Fischman, 1995).

2. Methods

Prior to beginning data collection, the experimental design and analyses were registered and made public on AsPredicted.org (https://aspredicted.org/public/204812627.pdf).

2.1. Participants

Seventy right-handed, young adults (43 females, M_{age} = 21.7, *SD* = 2.09 years) completed the experiment after providing informed written consent to an institution-approved research protocol. (One participant from the choice group was excluded for failing to meet inclusion criteria (recent musculoskeletal injury), while three participants (two in the yoked group) had their EEG data excluded due to excessive artifact). Handedness was determined by the Edinburgh Handedness Inventory (Oldfield, 1971). Participants were recruited from university courses and by word-of-mouth, and were compensated with course credit when possible. The participants were quasi-randomly assigned to a choice (choice, *n* = 35) or (yoked, *n* = 35) group (sex was matched in order to ensure that each male was yoked to a male, and each female to a female). Sample size was determined with an a priori power calculation based on the least powerful primary analysis (i.e., the sample size was adequately powered for all primary analyses). Specifically, the power calculation was designed to reach 80% power ($\alpha \leq .05$) to detect a moderate-sized effect (f^2 = .15) of FRN/RewP and motivation on motor learning, controlling for baseline (pretest) motor skill performance and group (choice/yoked) in a multiple regression model (fixed model, R^2 increase) (Faul, Erdfelder, Lang, & Buchner, 2007). The calculation yielded a sample size of 68, but 70 participants signed up for the study and all completed it.

2.2. Task

Participants sat in a chair and tossed a beanbag over a board (187 × 122.5 cm) that occluded their vision of the target. A table (73.5 cm high) sat between the participant and the board and a computer monitor (38.5 cm) sat on the table, 75 cm from the participant (see Experiment 1 Figure 1).

Participants grasped the beanbag with their left hand over the beanbag and released the beanbag while elevating their arm to toss the beanbag over the occlusion board. Their objective was to hit the bull's eye of a circular target placed on the floor 300 cm away. The bull's eye had a radius of 10 cm, and was surrounded by eight concentric circles, each of which increased the radius by 10 cm. The result of each toss was determined by measuring the distance from the *x*- and *y*-axes passing through the center of the bull's eye to the part of the beanbag closest to the respective axis. From these results, radial error (RE) and bivariate variable error (BVE) were derived.

2.3. Procedure

Upon arriving to the laboratory and after providing consent, participants were given an overview of the study procedures, specific to their group (they remained blind to the hypotheses of the study). Next, they were shown the color legend used for augmented feedback to ensure that they could discriminate the colors on the legend.

2.3.1. Pretest

Ten trials of the task were completed using a white beanbag. Participants were allowed to view the target prior to the pretest, but no feedback was given during the pretest. Participants received a 1.5 min break before proceeding with the acquisition phase of the study.

2.3.2. Acquisition

This phase consisted of 10 blocks of 10 trials with approximately 1 min breaks between each block. Participants were allowed to view the target prior to each block. Choice participants were asked before every block what color beanbag they would like (blue, red, yellow, green), whereas yoked participants were told the color they would be using for the block (their beanbag color was yoked to a counterpart in the choice group). Augmented feedback was presented on the computer monitor as follows (Figure 8). First, a legend displaying a color spectrum consisting of 10 color steps was presented in the center of the monitor for 3000 ms (each color step corresponds to how close a toss came to the bull's eye (e.g., red = bull's eye…dark blue = missed the target completely). For half of the participants in each group, 'warmer' colors indicated greater accuracy; for the other half of participants, 'cooler' colors indicated greater accuracy. After the legend disappeared, a fixation cross (+) appeared in its place for 3000 ms. Then an arrow, the color of which corresponded to the accuracy of the toss, appeared just above the fixation cross for 1000 ms. The arrow also indicated the direction of the toss relative to the target (long, long right, right, short right, short, short left, left, long left), unless the toss was a bull's eye, in which case just a rectangle with the bull's eye color was displayed.

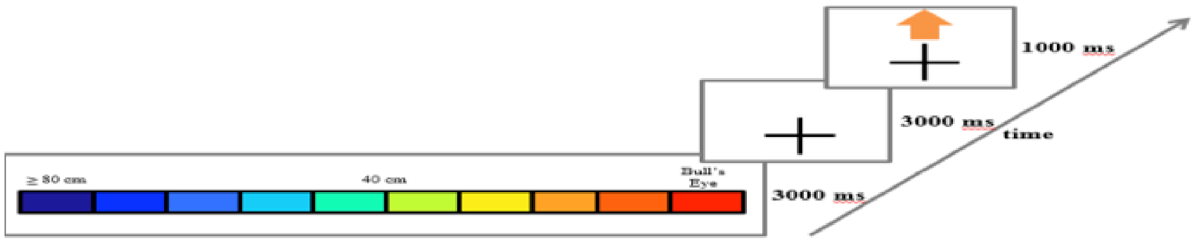

Figure 8. A pictorial representation of augmented feedback.

During acquisition, scalp EEG was collected from 32 channels of an EEG cap housing a 64 channel BrainVision actiCAP system (Brain Products GmbH, Munich, Germany) labeled in accord with an extended international 10–20 system (Oostenveld & Praamstra, 2001). EEG data were online-referenced to the left earlobe, and a common ground was employed at the FPz electrode site. Electrode impedances were maintained below 25 kΩ throughout the study and a high-pass filter was set at 0.016 Hz with a sampling rate of 250 Hz. The EEG signal was amplified and digitized with a BrainAmp DC amplifier (Brain Products GmbH) linked to BrainVision Recorder software (Brain Products GmbH). After acquisition trials, participants completed the IMI. The subscales of interest were as follows: interest/enjoyment (intrinsic motivation), value/usefulness (internalized motivation), and effort/importance (general motivation). All responses were made on a seven-point Likert scale, anchored by “not true at all” and “very true.”

2.3.3. Retention and Transfer

Approximately one week after completing acquisition, participants completed retention and transfer tests. The retention test was the same as pretest. The transfer test had the same physical parameters as retention, but the experimental treatment for each group was reversed from their practice condition in order to differentiate learning and performance effects.

Specifically, if the participant was in the choice group during acquisition they were randomly assigned to one of the four colors, whereas if the participant was in the yoked group during acquisition they were able to choose one of the four colors.

2.4. Data Processing

2.4.1. Performance

RE (accuracy) and BVE (precision) were calculated as recommended by Hancock, Butler, and Fischman (1995).

2.4.2. EEG

EEG data processing was conducted with BrainVision Analyzer 2.1 software (BrainProducts GmbH, Munich, Germany). Data were re-referenced to an averaged ears montage, band-passed filtered between 0.1 and 30 Hz with 4th order rolloffs and a 60 Hz notch filter employing a zero phase shift Butterworth filter. Next, eye-blinks were reduced by employing the ICA-based ocular artifact rejection function within the BrainVision Analyzer software (electrode FP2 served as the VEOG channel; BrainProducts, 2013). This function searches for an ocular artifact template in channel FP2, and then finds ICA-derived components that account for a user specified (70%) amount of variance in the template matched portion of the signal from FP2. These components were removed from the EEG signal, which was then reconstructed for further processing. ERPs were obtained by extracting the epoch of 200 ms prior to feedback onset through 1000 ms post-feedback onset, then baseline correcting with reference to the pre-stimulus interval. ERPs with a 50 µV change from one data point to the next at midline electrodes (Fz, FCz, Cz, CPz, and Pz) or a 100 µV change within a moving 200-ms window were excluded from subsequent analysis. This yielded rejection of 14.6% of trials. The remaining epochs were then averaged. Grand averages for both groups were computed and visually inspected. These averages revealed a positivity in the FRN/RewP time window (Figure 9). Next, we sought to quantify the RewP. Since there were substantial inter-individual differences in RewP latency, an adaptive time window was employed to calculate mean amplitude (Clayson, Baldwin, and Larson, 2013). Specifically, each participant's peak positive voltage between 200 and 400 ms at Fz was identified. Next, a 40 ms time window around the Peak was created, from which mean amplitude was calculated.

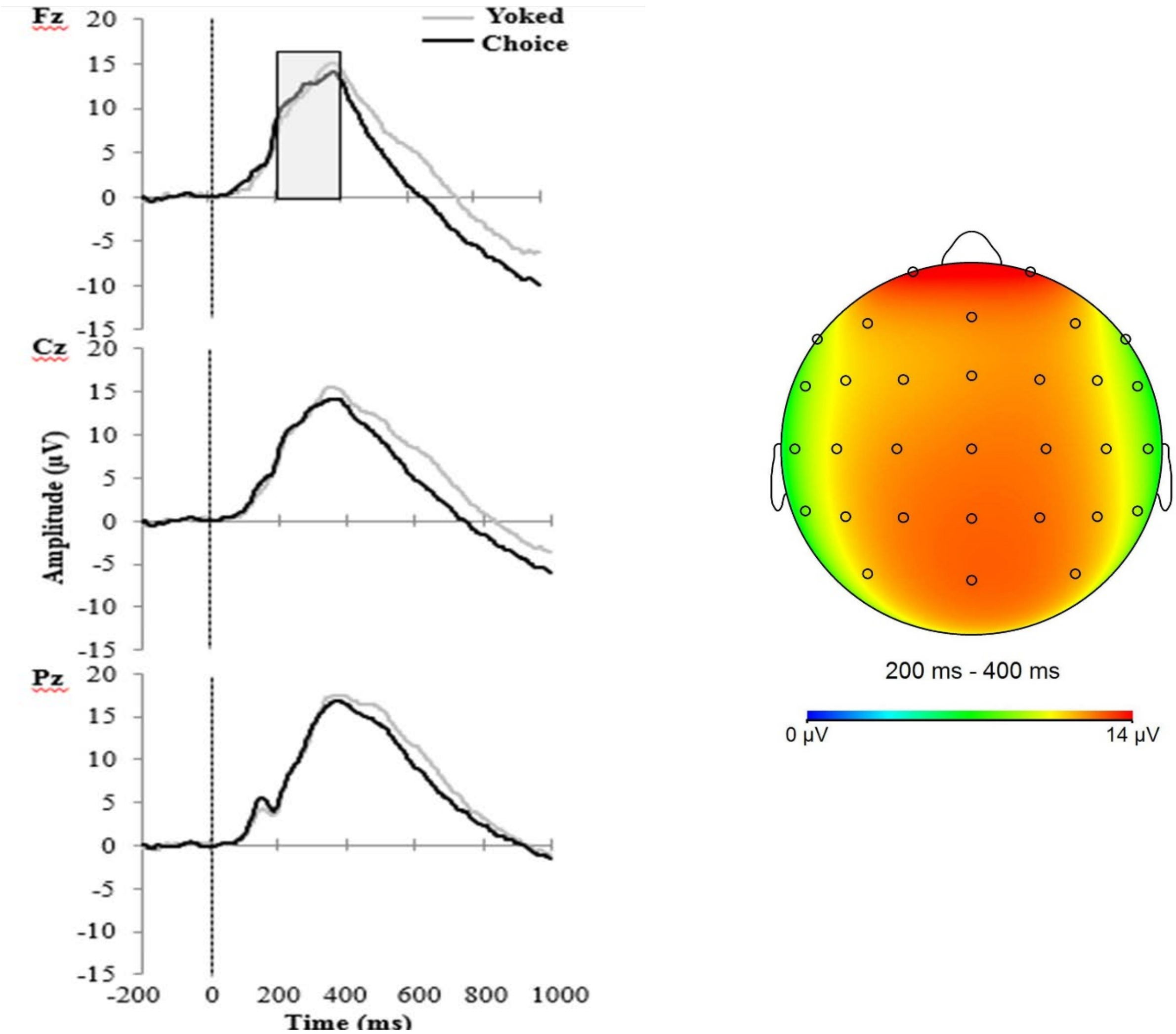

Figure 9. (Left) RewP mean amplitude grand averages for the yoked and choice group, the RewP was isolated in time window represented by the grey box. **(Right)** RewP topography averaged across groups. The topography is similar to those of the RewP reported in studies employing feedback stimuli (Meadows, Gable, Lohse, & Miller, 2016), suggesting the component identified in is indeed the RewP.

2.5. Statistical Analysis

To assess acquisition performance differences between the groups, separate mixed-factor ANCOVAs were conducted for RE and BVE with group (choice or no choice) serving as the between-subjects factor, acquisition block serving as the within-subjects factor, and pretest RE or BVE (depending on the ANCOVA's dependent variable) serving as the covariate. IMI subscale scores were analyzed using a MANOVA with group serving as the independent variable. RewP amplitude was analyzed using an independent sample *t*-test with group serving as the independent variable.

In order to measure learning as a function of group, separate mixed-factor ANCOVAs for RE and BVE were conducted with group serving as the between-subjects factor, posttest (retention or transfer) serving as the within-subjects factor, and pretest RE/BVE serving as the covariate.

In order to determine the effect of IMI and RewP on learning, stepwise regressions were conducted for RE and BVE, separately. We hoped to average RE and BVE across posttest in order to reduce the number of regressions conducted (see Lohse, Buchanan, & Miller, in press). This averaging would be justified by the absence of significant Group x Posttest interactions in the mixed-factor ANCOVAs described in the previous paragraph. The first-step of the regressions included pretest RE or BVE and group as predictors. The second step added in IMI and RewP as predictors. Thus, the critical comparison is the *r*-squared change from Step 1 to Step 2, testing the importance of IMI and RewP on posttest performance controlling for pretest and group assignment. Alpha levels were set to .05 for all tests and all confidence intervals are set at 95%. The Greenhouse-Geisser correction is employed when sphericity was violated.

3. Hypotheses

It was predicted that choice participants would exhibit (1) superior learning, as indicated by significantly greater accuracy (lower RE) and precision (lower BVE) on the retention and transfer tests; (2) choice participants would report significantly higher IMI scores on all subscales; (3) RewP amplitude would be greater for the choice group; and (4) both RewP amplitude and IMI scores would predict greater accuracy and precision.

4. Results

RE by group across all experimental phases is depicted in Figure 11, and BVE by group across all phases is depicted in Figure 12.

4.1. Acquisition

No significant effects for group, block, or the Group x Block interaction were observed for RE (ps $\geq .463$) or BVE (ps $\geq .229$).

4.2. IMI

The MANOVA testing group differences in the interest/enjoyment, value/usefulness, and effort/importance subscales of the IMI revealed a nonsignificant effect ($F(3, 65) = 0.626$, $p = .601$, Wilk's $\Lambda = 0.927$.

4.3. RewP

The group's did not differ with respect to RewP amplitude ($t(64) = 0.165$, $p = .870$).

4.4. Posttests

No significant effects for group, posttest, or the Group x Posttest interaction were observed for RE (*p*s $\geq$ .245) or BVE (*p*s $\geq$ .350). To determine whether there was indeed a learning effect to be moderated by group, a one-way (Test: Pretest/Retention/Transfer) repeated measures ANOVA was conducted for both RE and BVE. For RE, results revealed a significant effect of test ($F(1.46, 99.6) = 38.9$, $p < .001$, $\eta^2_p = .364$, $\varepsilon = .732$), and post-hoc Fisher LSD tests indicated the participants were significantly more accurate on the retention (*M* = 45.3, *CI* = 41.4 – 49.2) and transfer (*M* = 45.1, *CI* = 40.9 – 49.2) tests relative to the pretest (*M* = 66.8, *CI* = 60.7 – 72.9) (*p*s < .001). Similarly for BVE, results revealed a significant effect of test ($F(2, 136) = 6.09$, $p < .001$, $\eta^2_p = .082$), and post-hoc Fisher LSD tests indicated the participants were significantly more precise on the retention (*M* = 39.0, *CI* = 35.4 – 42.7) and transfer (*M* = 37.1, *CI* = 33.9 – 40.2) tests relative to the pretest (*M* = 44.7, *CI* = 40.8 – 48.6) (*p*s $\leq$ .029).

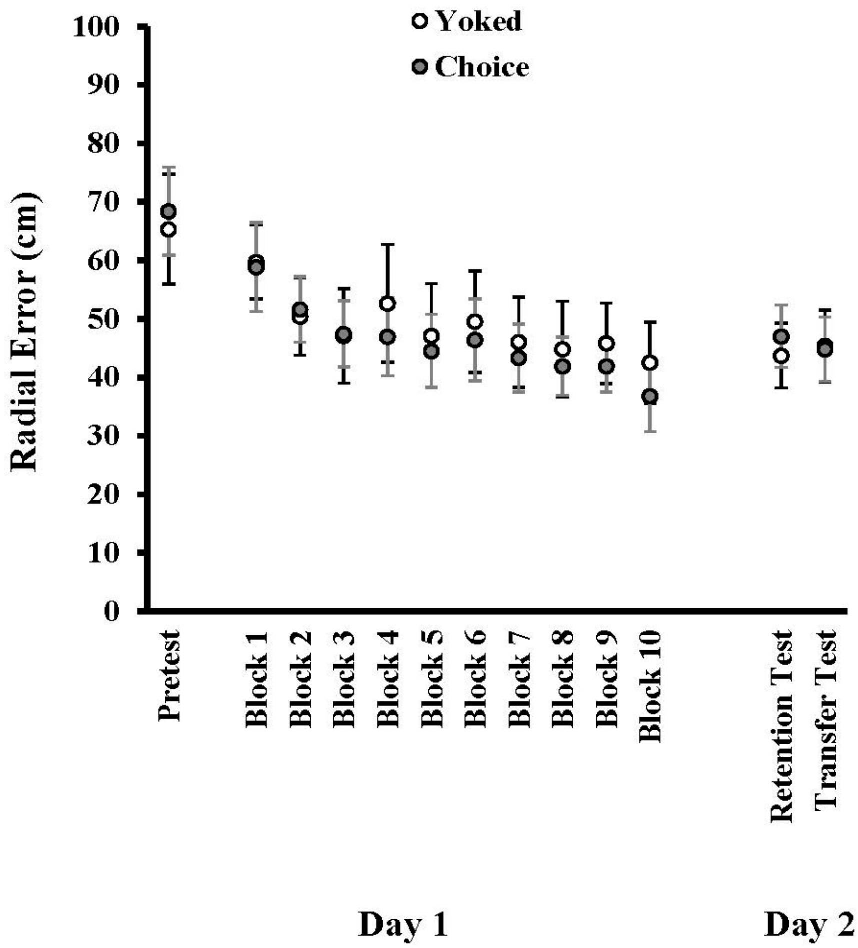

Figure 10. Accuracy (radial error) during pretest, acquisition, retention, and transfer phases for choice and yoked groups. Error bars represent 95% *CIs*.

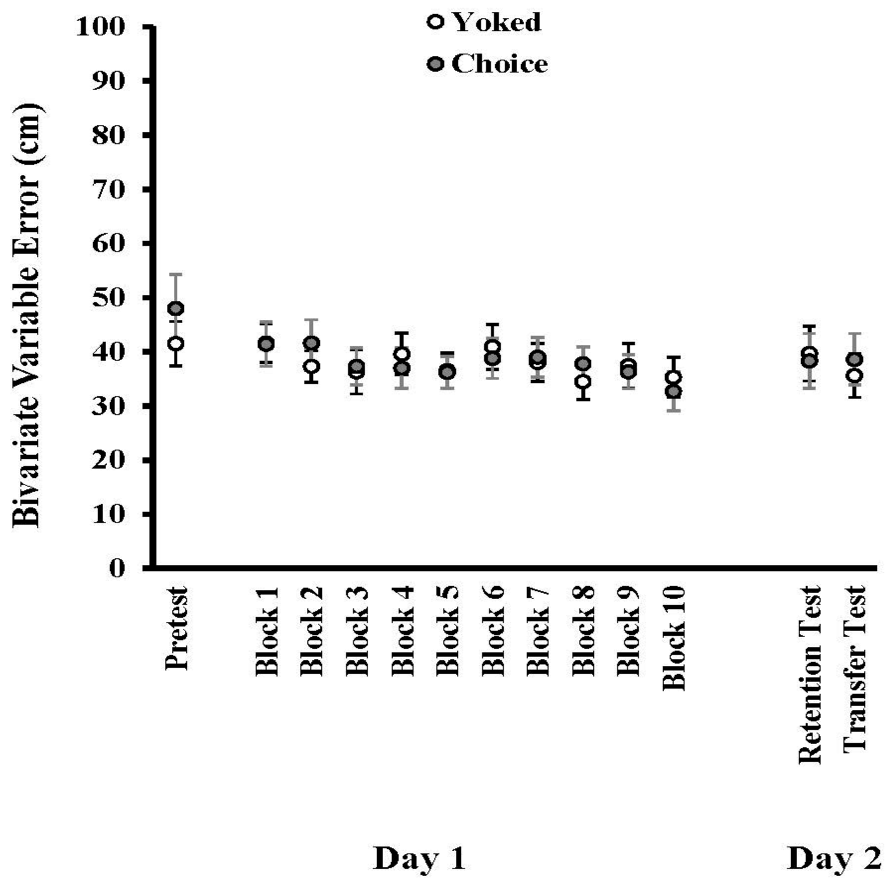

Figure 11. Precision (bivariate variable error) during pretest, acquisition, retention, and transfer phases for choice and yoked groups. Error bars represent 95% *CIs*.

4.5. Relationships between IMI, RewP, and Motor Learning

Since there were no significant Group x Posttest interactions, retention and transfer tests were averaged together. After controlling for pretest and group, IMI (averaged across interest/enjoyment, value/usefulness, and effort/importance subscales) and RewP failed to explain additional variance in posttest RE (R^2 change = .012, p = .671), and neither variable was a significant predictor of posttest RE (ps $\geq$ .425; see Figures 12 - 13). After controlling for pretest and group, IMI and RewP failed to explain additional variance in posttest BVE (R^2 change = .004, p = .884), and neither variable was a significant predictor of posttest RE (ps $\geq$ .647.

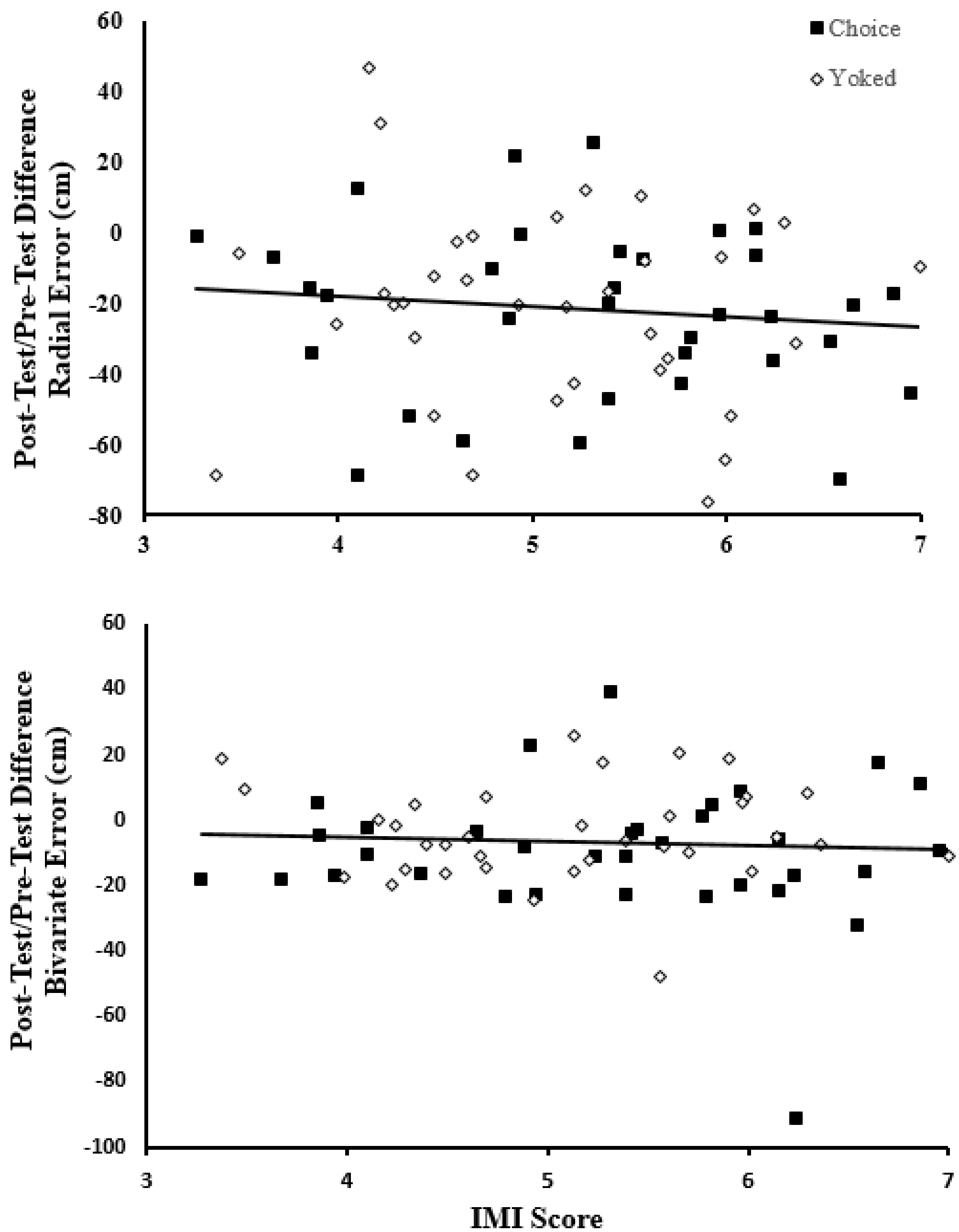

Figure 12. (Top) Correlation examining relationship between IMI score and the radial error difference between retention and pre-test. **(Bottom)** A correlation examining relationship between IMI score and the bivariate variable error difference between retention and pre-test.

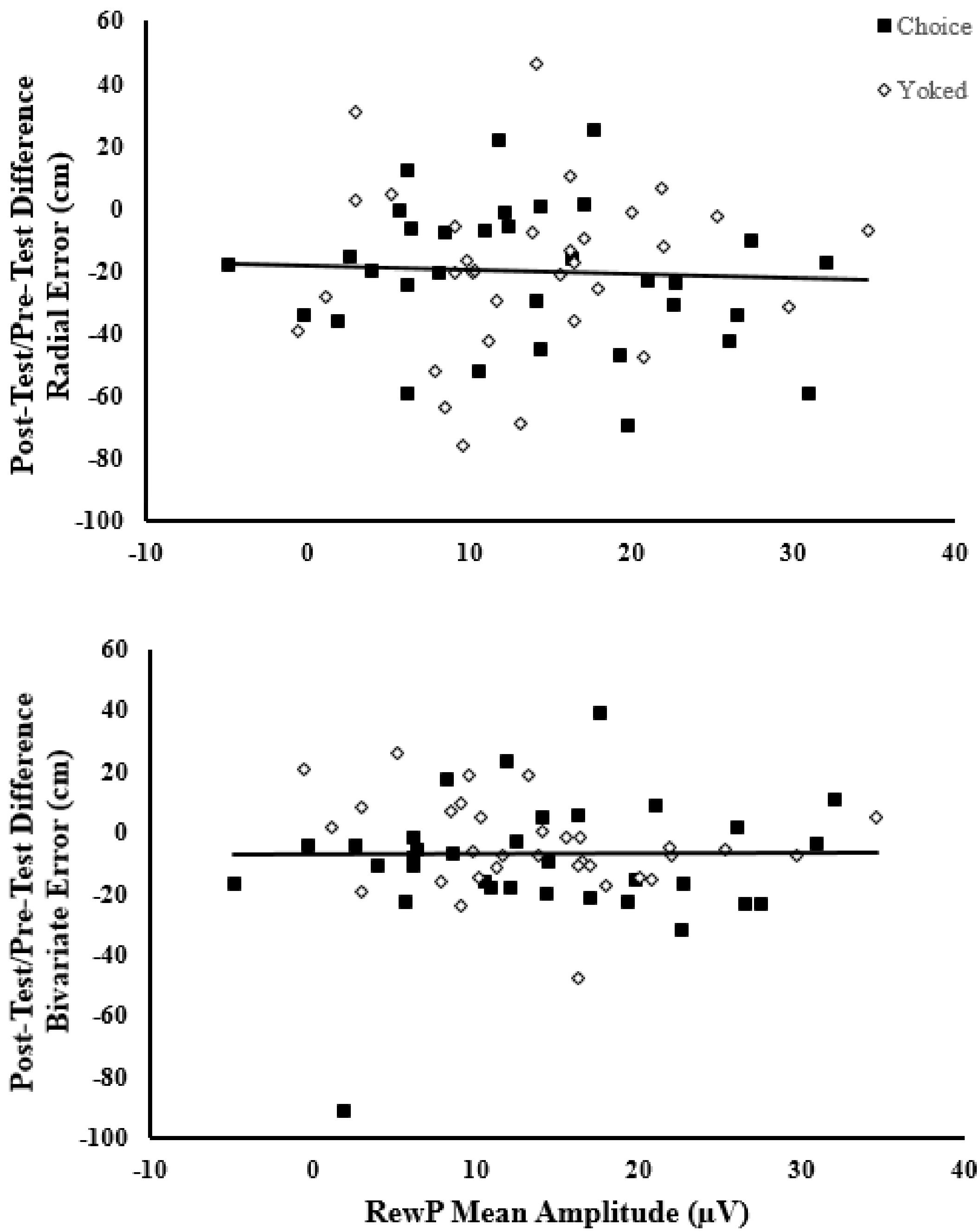

Figure 13. (Top) Correlation examining relationship between RewP mean amplitude and the radial error difference between retention and pre-test. **(Bottom)** Correlation examining relationship between RewP mean amplitude and the radial error difference between retention and pre-test.

4.6. Relationships between IMI, RewP, and Motor Performance during Acquisition

To assess the relationship between IMI scores, RewP mean amplitude and motor performance during acquisition, exploratory partial correlations (controlling for group) were conducted. The analyses revealed that there was a significant correlation between IMI score and the change in RE from block 1 to block 10 during acquisition ($p < .001$, r = -.496, see Figure 14). Similarly, RewP mean amplitude and the change in RE from block 1 to block 10 during acquisition were significantly correlated ($p = .032$, r = -.266, see Figure 15). However, neither IMI score nor RewP mean amplitude was significantly correlated with change in BVE from block 1 to block 10 during acquisition. Finally, a significant correlation between IMI score and RewP mean amplitude was observed ($p = .037$, r = .259, see Figure 16). Together, these results suggest motivation and feedback processing are associated with positive changes in accuracy during practice, and that motivation is associated with feedback processing.

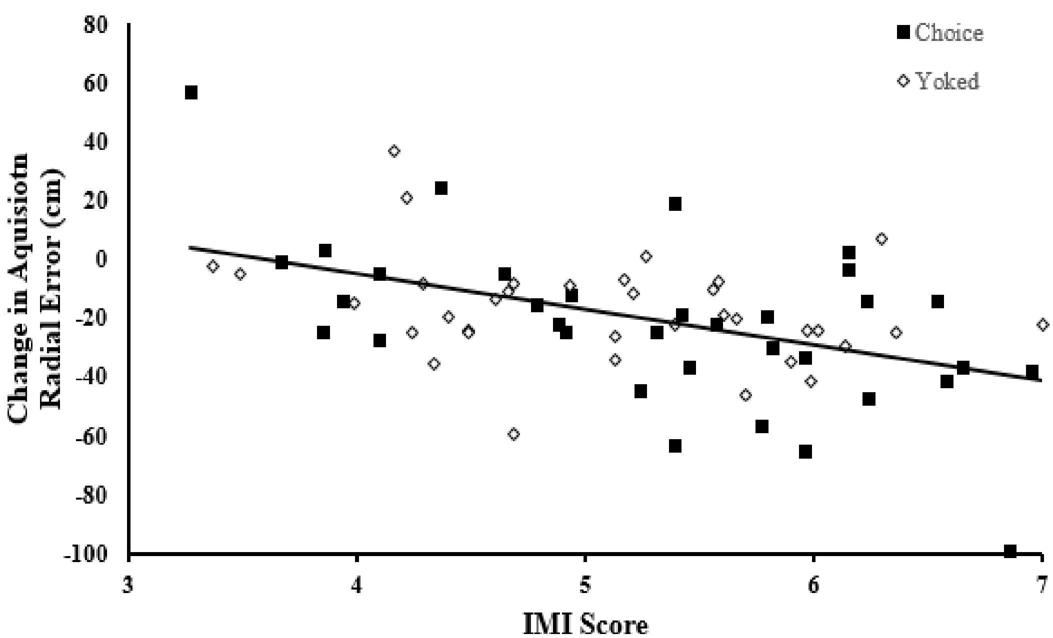

Figure 14. Correlation examining the relationship between IMI score and the radial error difference between block 10 and block 1 of acquisition. (Negative values on the y-axis indicate adaptive changes)

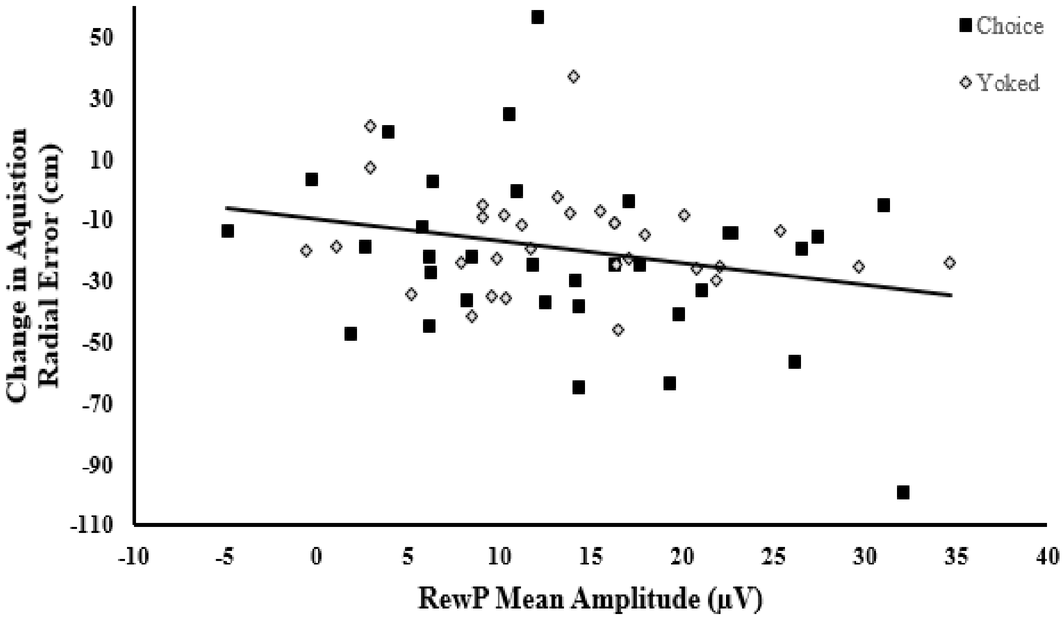

Figure 15. Correlation examining relationship between RewP mean amplitude and the radial error difference between block 10 and block 1 of acquisition. (Negative values on the y-axis indicate adaptive changes).

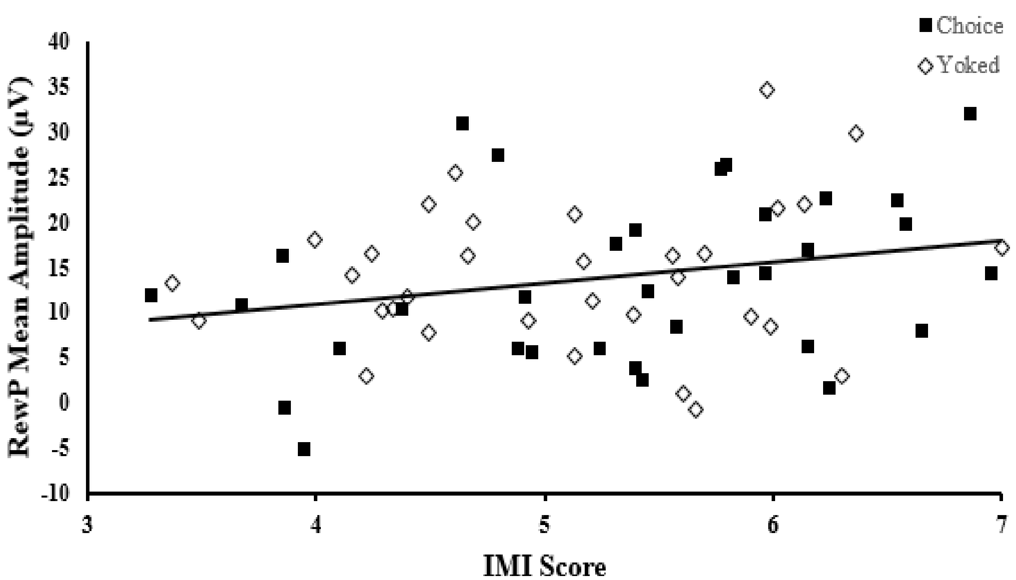

Figure 16. Correlation examining relationship between IMI score and RewP mean amplitude during acquisition.

5. Discussion

The purpose of the present study was to test the hypothesis that an incidental choice enhances motor learning and to investigate the possible mechanisms of the enhancement. Specifically, we investigated whether motivation and augmented feedback processing increase when given an incidental choice, and whether these factors generally predict learning (controlling for whether an incidental choice is given). The results show that an incidental choice did not enhance motor learning. Additionally, choice participants did not exhibit significant enhancements in motivation (IMI scores) or feedback processing (RewP amplitude), neither of which predicted motor learning.

The results are inconsistent with previous incidental choice studies demonstrating improved learning, even though our paradigm was similar to these studies (Lewthwaite et al., 2015; Wulf, & Adams 2014; Wulf, Chiviacowsky, & Cardozo, 2014). A couple of reasons could explain this discrepancy. First, the incidental choice effect may not be robust to minor experimental changes. For example, participants in the present study relied heavily on augmented feedback, whereas participants in the other incidental choice studies had intrinsic feedback more readily available (i.e., they could see the outcome of each trial execution). While this might explain the discrepancy between the current null-result and previous findings, if the incidental choice effect is not robust, then the importance of providing incidental choices during practice is questionable. Second, the present experiment was more highly-powered (larger *N* and employed a pretest as a covariate) than the other studies demonstrating an incidental choice does enhance motor learning. Thus, it is possible our study provides a more precise measurement of the incidental choice phenomenon (or lack thereof).

Based on the current results, the group difference feedback processing result found in Grand et al. (2015) seems more attributable to the fact that participants received feedback when they thought it would be useful, thereby increasing their processing of the feedback (i.e., the utility account of feedback processing [Arbel, Murphy, & Donchin, 2014]). In addition to the usefulness of the feedback, the choice over when to receive it may tailor the practice conditions to the learner's needs, which would lead them to be more involved in the learning process, thus causing them to process the feedback to a greater extent (Chiviacowsky & Wulf, 2005). Therefore, autonomy manipulations may have to be related to the feedback schedule to enhance feedback processing. Although, feedback processing appeared to predict motor learning in Grand et al., current results do not support that finding. Although it is difficult to compare findings across different experiments, this discrepancy might be explained by the nature of the autonomy manipulation in the two different studies. In the current experiment, autonomy was increased over a task-irrelevant variable (i.e., bean-bag color) whereas in Grand et al. (2015) autonomy was given over the feedback-schedule itself, suggesting that relationship between feedback processing and learning might be moderated by how autonomy is manipulated. (This position is speculative, however, as participants were not randomly assigned to the two different experiments and the experiment by Grand et al. (2015) was not specifically powered to detect a relationship between feedback processing and motor learning.)

IMI scores did not differ between groups, indicating that the incidental choice did not influence motivation. This is in contrast to the results found in Grand et al. (2015) where the self-controlled feedback group reported significantly higher IMI scores then their yoked counterparts. This may be due to the fact that the participants generally chose to receive feedback after more accurate tosses, which may have enhanced their perceived competence, thereby increasing motivation. The results also indicated that intrinsic motivation, regardless of group, did not predict motor learning. This is now one of several recent studies showing that motivation, as measured through self-report, does not predict motor learning (Carter, Carlesen, Ste-Marie, 2014; Daou et al., in press; Leiker et al., 2016; Lohse et al., 2015). It is becoming more evident that motivation, as we currently measure it (via self-report), does not predict motor learning.

While motivation and RewP mean amplitude didn't predict motor learning, the exploratory analyses revealed that motivation and RewP mean amplitude did predict positive changes in performance during practice (in terms of accuracy). These results are congruent with the fact that motivation is positively associated with performance, and with the research demonstrating FRN/RewP amplitude predicts positive adaptations in performance (e.g., Holroyd & Krigolson, 2007; Van DerHelden, Boksem, & Blom, 2009). Notably, some studies relating FRN/RewP amplitude to motor learning/performance claim that the ERP components do indeed predict motor learning (e.g., Van DerHelden et al., 2009), yet these studies do not include delayed-retention tests, which are necessary to infer learning as defined by relatively permanent changes in motor performance capability (e.g., Schmidt & Lee, 2014). Thus, taken together with the present results, it may the case that the FRN/RewP are associated with changes in practice performance but not motor learning.

It is notable that IMI scores were positively correlated with increased RewP mean amplitude. The increase in RewP mean amplitude as a function of IMI score suggests that if a person is more motivated during practice, they exhibit an increase in feedback processing, which has a positive influence on performance adaption (although maybe not motor learning). The relationship between the IMI and RewP is also notable because although many studies have associated proxies of motivation, such as monetary rewards (e.g., Meadows, Gable, Lohse, &

Miller, 2016), with RewP amplitude, there are relatively few studies that have demonstrated self-reported motivation to be associated with feedback processing.

Conclusions

Although careful consideration was taken to replicate the paradigm used in previous incidental choice studies (e.g., Lewthwaite, et al., 2015), the present study casts doubt on the benefits of incidental choices during practice to motor learning and failed to elucidate potential mechanisms underlying the effect, if it is indeed reliable. Autonomy is a complex construct and manipulating autonomy seems to be a complicated endeavor with many interacting variables involved. Further investigation is needed to clarify if task-irrelevant incidental choices presented in a laboratory setting do in fact manipulate autonomy (as defined in self-determination theory), which has been suggested to enhance motor learning. Perhaps other variables, such as the relationship to the one offering the choice, are more important, and in certain instances (i.e. coach and athlete) the choice may mediate feelings of autonomy and self-determinism. Other variables such as the age of the person receiving the choice may influence the choice's effect on autonomy; color choice, for instance, may mean more to a child than it does to the average college student. It is important to note that many human interactions are not black and white, and before we can categorically say that incidental choices do not matter, more color needs to be added to the picture. However, the current results do suggest that motivation may be more strongly associated with performance during practice than long-term retention, and suggest that incidental choices are not a powerful mechanism for augmenting motor-skill learning.

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Appendix 1

ANCOVA__Radial Error

Within-Subjects Factors

Measure: MEASURE_1

Block	Dependent Variable
1	Acq_1_RE
2	Acq_2_RE
3	Acq_3_RE
4	Acq_4_RE
5	Acq_5_RE
6	Acq_6_RE
7	Acq_7_RE
8	Acq_8_RE
9	Acq_9_RE
10	Acq_10_RE

Between-Subjects Factors

		N
Group	-1.00	35
	1.00	34

Descriptive Statistics

	Group	Mean	Std. Deviation	N
Acq_1_RE	-1.00	59.7086	19.19082	35
	1.00	58.8335	22.61773	34
	Total	59.2774	20.79894	69
Acq_2_RE	-1.00	50.3566	20.11339	35
	1.00	51.6115	16.66331	34
	Total	50.9749	18.36908	69
Acq_3_RE	-1.00	47.1014	24.39333	35
	1.00	47.3897	16.71389	34
	Total	47.2435	20.81123	69
Acq_4_RE	-1.00	52.6483	32.75344	35
	1.00	46.8756	19.68645	34
	Total	49.8038	27.07258	69
Acq_5_RE	-1.00	47.0840	26.76769	35
	1.00	44.4544	18.57716	34
	Total	45.7883	22.96712	69
Acq_6_RE	-1.00	49.4934	26.06794	35
	1.00	46.3815	20.72555	34
	Total	47.9600	23.46662	69
Acq_7_RE	-1.00	45.9951	23.19847	35
	1.00	43.3088	17.31321	34
	Total	44.6714	20.40540	69
Acq_8_RE	-1.00	44.7566	24.70375	35
	1.00	41.9032	14.81630	34
	Total	43.3506	20.34049	69
Acq_9_RE	-1.00	45.8329	20.70282	35
	1.00	41.8565	13.14213	34
	Total	43.8735	17.38193	69
Acq_10_RE	-1.00	42.5226	20.80082	35
	1.00	36.7750	17.96374	34
	Total	39.6904	19.52736	69

Box's Test of Equality of Covariance Matrices[a]

Box's M	109.429
F	1.673
df1	55
df2	14470.237
Sig.	.001

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Block	Pillai's Trace	.124	.914[b]	9.000	58.000	.519	.124
	Wilks' Lambda	.876	.914[b]	9.000	58.000	.519	.124
	Hotelling's Trace	.142	.914[b]	9.000	58.000	.519	.124
	Roy's Largest Root	.142	.914[b]	9.000	58.000	.519	.124
Block * Pretest_RE	Pillai's Trace	.233	1.959[b]	9.000	58.000	.061	.233
	Wilks' Lambda	.767	1.959[b]	9.000	58.000	.061	.233
	Hotelling's Trace	.304	1.959[b]	9.000	58.000	.061	.233
	Roy's Largest Root	.304	1.959[b]	9.000	58.000	.061	.233
Block * Group	Pillai's Trace	.059	.407[b]	9.000	58.000	.926	.059
	Wilks' Lambda	.941	.407[b]	9.000	58.000	.926	.059
	Hotelling's Trace	.063	.407[b]	9.000	58.000	.926	.059
	Roy's Largest Root	.063	.407[b]	9.000	58.000	.926	.059

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Block	Sphericity Assumed	1146.095	9	127.344	.783	.632	.012
	Greenhouse-Geisser	1146.095	5.323	215.317	.783	.569	.012
	Huynh-Feldt	1146.095	6.020	190.382	.783	.584	.012
	Lower-bound	1146.095	1.000	1146.095	.783	.379	.012
Block * Pretest_RE	Sphericity Assumed	5014.700	9	557.189	3.428	.000	.049
	Greenhouse-Geisser	5014.700	5.323	942.112	3.428	.004	.049
	Huynh-Feldt	5014.700	6.020	833.010	3.428	.003	.049
	Lower-bound	5014.700	1.000	5014.700	3.428	.069	.049
Block * Group	Sphericity Assumed	676.594	9	75.177	.463	.900	.007
	Greenhouse-Geisser	676.594	5.323	127.112	.463	.815	.007
	Huynh-Feldt	676.594	6.020	112.391	.463	.837	.007
	Lower-bound	676.594	1.000	676.594	.463	.499	.007
Error(Block)	Sphericity Assumed	96551.642	594	162.545			
	Greenhouse-Geisser	96551.642	351.307	274.836			
	Huynh-Feldt	96551.642	397.318	243.008			
	Lower-bound	96551.642	66.000	1462.904			

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Block	.060	176.750	44	.000	.591	.669	.111

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
Acq_1_RE	.351	1	67	.556
Acq_2_RE	.011	1	67	.915
Acq_3_RE	.260	1	67	.612
Acq_4_RE	1.385	1	67	.243
Acq_5_RE	.916	1	67	.342
Acq_6_RE	1.065	1	67	.306
Acq_7_RE	2.306	1	67	.134
Acq_8_RE	1.912	1	67	.171
Acq_9_RE	5.037	1	67	.028
Acq_10_RE	.707	1	67	.404

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	120006.628	1	120006.628	40.632	.000	.381
Pretest_RE	9381.005	1	9381.005	3.176	.079	.046
Group	1611.898	1	1611.898	.546	.463	.008
Error	194932.067	66	2953.516			

ANCOVA__Bivariate Variable Error

Within-Subjects Factors

Measure: MEASURE_1

Block	Dependent Variable
1	Acq_1_VE
2	Acq_2_VE
3	Acq_3_VE
4	Acq_4_VE
5	Acq_5_VE
6	Acq_6_VE
7	Acq_7_VE
8	Acq_8_VE
9	Acq_9_VE
10	Acq_10_VE

Between-Subjects Factors

		N
Group	-1.00	35
	1.00	34

Descriptive Statistics

	Group	Mean	Std. Deviation	N
Acq_1_VE	-1.00	41.5666	10.67704	35
	1.00	41.3815	12.07315	34
	Total	41.4754	11.30244	69
Acq_2_VE	-1.00	37.3306	8.73133	35
	1.00	41.5535	12.79742	34
	Total	39.4114	11.05077	69
Acq_3_VE	-1.00	36.3029	12.27396	35
	1.00	37.2706	10.08250	34
	Total	36.7797	11.17569	69
Acq_4_VE	-1.00	39.5963	11.49847	35
	1.00	37.0224	11.06098	34
	Total	38.3280	11.27658	69
Acq_5_VE	-1.00	36.5394	9.88269	35
	1.00	36.2341	8.66270	34
	Total	36.3890	9.23445	69
Acq_6_VE	-1.00	40.9040	12.62991	35
	1.00	38.8224	11.11305	34
	Total	39.8783	11.86550	69
Acq_7_VE	-1.00	37.9726	10.56941	35
	1.00	38.9918	10.84136	34
	Total	38.4748	10.63761	69
Acq_8_VE	-1.00	34.4569	9.86401	35
	1.00	37.7668	9.21600	34
	Total	36.0878	9.62529	69
Acq_9_VE	-1.00	37.3934	12.53612	35
	1.00	36.3212	9.32866	34
	Total	36.8651	11.00459	69
Acq_10_VE	-1.00	35.2623	11.03727	35
	1.00	32.7482	10.83856	34
	Total	34.0235	10.93267	69

Box's Test of Equality of Covariance Matrices[a]

Box's M	57.544
F	.880
df1	55
df2	14470.237
Sig.	.723

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Block	Pillai's Trace	.144	1.088[b]	9.000	58.000	.386	.144
	Wilks' Lambda	.856	1.088[b]	9.000	58.000	.386	.144
	Hotelling's Trace	.169	1.088[b]	9.000	58.000	.386	.144
	Roy's Largest Root	.169	1.088[b]	9.000	58.000	.386	.144
Block * Pretest_VE	Pillai's Trace	.098	.703[b]	9.000	58.000	.703	.098
	Wilks' Lambda	.902	.703[b]	9.000	58.000	.703	.098
	Hotelling's Trace	.109	.703[b]	9.000	58.000	.703	.098
	Roy's Largest Root	.109	.703[b]	9.000	58.000	.703	.098
Block * Group	Pillai's Trace	.142	1.064[b]	9.000	58.000	.403	.142
	Wilks' Lambda	.858	1.064[b]	9.000	58.000	.403	.142
	Hotelling's Trace	.165	1.064[b]	9.000	58.000	.403	.142
	Roy's Largest Root	.165	1.064[b]	9.000	58.000	.403	.142

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Block	Sphericity Assumed	958.799	9	106.533	1.309	.229	.019
	Greenhouse-Geisser	958.799	7.697	124.571	1.309	.239	.019
	Huynh-Feldt	958.799	9.000	106.533	1.309	.229	.019
	Lower-bound	958.799	1.000	958.799	1.309	.257	.019
Block * Pretest_VE	Sphericity Assumed	495.119	9	55.013	.676	.731	.010
	Greenhouse-Geisser	495.119	7.697	64.328	.676	.707	.010
	Huynh-Feldt	495.119	9.000	55.013	.676	.731	.010
	Lower-bound	495.119	1.000	495.119	.676	.414	.010
Block * Group	Sphericity Assumed	826.707	9	91.856	1.128	.340	.017
	Greenhouse-Geisser	826.707	7.697	107.409	1.128	.343	.017
	Huynh-Feldt	826.707	9.000	91.856	1.128	.340	.017
	Lower-bound	826.707	1.000	826.707	1.128	.292	.017
Error(Block)	Sphericity Assumed	48350.231	594	81.398			
	Greenhouse-Geisser	48350.231	507.990	95.179			
	Huynh-Feldt	48350.231	594.000	81.398			
	Lower-bound	48350.231	66.000	732.579			

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Block	.499	43.703	44	.486	.855	1.000	.111

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
Acq_1_VE	.098	1	67	.755
Acq_2_VE	4.021	1	67	.049
Acq_3_VE	.664	1	67	.418
Acq_4_VE	.118	1	67	.732
Acq_5_VE	.198	1	67	.657
Acq_6_VE	.276	1	67	.601
Acq_7_VE	1.222	1	67	.273
Acq_8_VE	.112	1	67	.739
Acq_9_VE	3.393	1	67	.070
Acq_10_VE	.005	1	67	.947

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	90874.939	1	90874.939	204.166	.000	.756
Pretest_VE	787.590	1	787.590	1.769	.188	.026
Group	21.949	1	21.949	.049	.825	.001
Error	29376.762	66	445.102			

MANOVA__IMI

Between-Subjects Factors

		N
Group	-1.00	35
	1.00	34

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.975	837.189[b]	3.000	65.000	.000
	Wilks' Lambda	.025	837.189[b]	3.000	65.000	.000
	Hotelling's Trace	38.639	837.189[b]	3.000	65.000	.000
	Roy's Largest Root	38.639	837.189[b]	3.000	65.000	.000
Group	Pillai's Trace	.028	.626[b]	3.000	65.000	.601
	Wilks' Lambda	.972	.626[b]	3.000	65.000	.601
	Hotelling's Trace	.029	.626[b]	3.000	65.000	.601
	Roy's Largest Root	.029	.626[b]	3.000	65.000	.601

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Interest	1.838[a]	1	1.838	1.520	.222
	Effort	1.187[b]	1	1.187	1.222	.273
	Value	.146[c]	1	.146	.073	.787
Intercept	Interest	1746.836	1	1746.836	1444.514	.000
	Effort	2203.107	1	2203.107	2267.915	.000
	Value	1673.001	1	1673.001	841.101	.000
Group	Interest	1.838	1	1.838	1.520	.222
	Effort	1.187	1	1.187	1.222	.273
	Value	.146	1	.146	.073	.787
Error	Interest	81.022	67	1.209		
	Effort	65.085	67	.971		
	Value	133.267	67	1.989		
Total	Interest	1828.421	69			
	Effort	2268.360	69			
	Value	1806.313	69			
Corrected Total	Interest	82.860	68			
	Effort	66.272	68			
	Value	133.413	68			

T-Test__RewP Mean Amplitude

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
All_RewP	-1.00	33	14.0145	7.93371	1.38108
	1.00	33	13.6658	9.23722	1.60799

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
All_RewP	Equal variances assumed	1.134	.291	.165	64	.870	.34879	2.11968	-3.88576	4.58333
	Equal variances not assumed			.165	62.574	.870	.34879	2.11968	-3.88761	4.58519

ANCOVA__Radial Error Retention and Transfer

Within-Subjects Factors

Measure: MEASURE_1

Test	Dependent Variable
1	Retention_RE
2	Transfer_RE

Between-Subjects Factors

		N
Group	-1.00	35
	1.00	34

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Test	Pillai's Trace	.012	.821[b]	1.000	66.000	.368
	Wilks' Lambda	.988	.821[b]	1.000	66.000	.368
	Hotelling's Trace	.012	.821[b]	1.000	66.000	.368
	Roy's Largest Root	.012	.821[b]	1.000	66.000	.368
Test * Pretest_RE	Pillai's Trace	.012	.825[b]	1.000	66.000	.367
	Wilks' Lambda	.988	.825[b]	1.000	66.000	.367
	Hotelling's Trace	.013	.825[b]	1.000	66.000	.367
	Roy's Largest Root	.013	.825[b]	1.000	66.000	.367
Test * Group	Pillai's Trace	.020	1.376[b]	1.000	66.000	.245
	Wilks' Lambda	.980	1.376[b]	1.000	66.000	.245
	Hotelling's Trace	.021	1.376[b]	1.000	66.000	.245
	Roy's Largest Root	.021	1.376[b]	1.000	66.000	.245

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Test	1.000	.000	0	.	1.000	1.000	1.000

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Test	Sphericity Assumed	89.738	1	89.738	.821	.368
	Greenhouse-Geisser	89.738	1.000	89.738	.821	.368
	Huynh-Feldt	89.738	1.000	89.738	.821	.368
	Lower-bound	89.738	1.000	89.738	.821	.368
Test * Pretest_RE	Sphericity Assumed	90.155	1	90.155	.825	.367
	Greenhouse-Geisser	90.155	1.000	90.155	.825	.367
	Huynh-Feldt	90.155	1.000	90.155	.825	.367
	Lower-bound	90.155	1.000	90.155	.825	.367
Test * Group	Sphericity Assumed	150.394	1	150.394	1.376	.245
	Greenhouse-Geisser	150.394	1.000	150.394	1.376	.245
	Huynh-Feldt	150.394	1.000	150.394	1.376	.245
	Lower-bound	150.394	1.000	150.394	1.376	.245
Error(Test)	Sphericity Assumed	7211.967	66	109.272		
	Greenhouse-Geisser	7211.967	66.000	109.272		
	Huynh-Feldt	7211.967	66.000	109.272		
	Lower-bound	7211.967	66.000	109.272		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Test	Type III Sum of Squares	df	Mean Square	F	Sig.
Test	Linear	89.738	1	89.738	.821	.368
Test * Pretest_RE	Linear	90.155	1	90.155	.825	.367
Test * Group	Linear	150.394	1	150.394	1.376	.245
Error(Test)	Linear	7211.967	66	109.272		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	20495.912	1	20495.912	47.687	.000
Pretest_RE	2198.092	1	2198.092	5.114	.027
Group	26.241	1	26.241	.061	.806
Error	28366.637	66	429.798		

ANCOVA__Bivariate Variable Error Retention and Transfer

Within-Subjects Factors

Measure: MEASURE_1

Test	Dependent Variable
1	Retention_VE
2	Transfer_VE

Between-Subjects Factors

		N
Group	-1.00	35
	1.00	34

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Test	Pillai's Trace	.013	.843[b]	1.000	66.000	.362
	Wilks' Lambda	.987	.843[b]	1.000	66.000	.362
	Hotelling's Trace	.013	.843[b]	1.000	66.000	.362
	Roy's Largest Root	.013	.843[b]	1.000	66.000	.362
Test * Pretest_VE	Pillai's Trace	.006	.410[b]	1.000	66.000	.524
	Wilks' Lambda	.994	.410[b]	1.000	66.000	.524
	Hotelling's Trace	.006	.410[b]	1.000	66.000	.524
	Roy's Largest Root	.006	.410[b]	1.000	66.000	.524
Test * Group	Pillai's Trace	.013	.886[b]	1.000	66.000	.350
	Wilks' Lambda	.987	.886[b]	1.000	66.000	.350
	Hotelling's Trace	.013	.886[b]	1.000	66.000	.350
	Roy's Largest Root	.013	.886[b]	1.000	66.000	.350

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Test	1.000	.000	0	.	1.000	1.000	1.000

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Test	Sphericity Assumed	120.181	1	120.181	.843	.362
	Greenhouse-Geisser	120.181	1.000	120.181	.843	.362
	Huynh-Feldt	120.181	1.000	120.181	.843	.362
	Lower-bound	120.181	1.000	120.181	.843	.362
Test * Pretest_VE	Sphericity Assumed	58.417	1	58.417	.410	.524
	Greenhouse-Geisser	58.417	1.000	58.417	.410	.524
	Huynh-Feldt	58.417	1.000	58.417	.410	.524
	Lower-bound	58.417	1.000	58.417	.410	.524
Test * Group	Sphericity Assumed	126.390	1	126.390	.886	.350
	Greenhouse-Geisser	126.390	1.000	126.390	.886	.350
	Huynh-Feldt	126.390	1.000	126.390	.886	.350
	Lower-bound	126.390	1.000	126.390	.886	.350
Error(Test)	Sphericity Assumed	9413.364	66	142.627		
	Greenhouse-Geisser	9413.364	66.000	142.627		
	Huynh-Feldt	9413.364	66.000	142.627		
	Lower-bound	9413.364	66.000	142.627		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Test	Type III Sum of Squares	df	Mean Square	F	Sig.
Test	Linear	120.181	1	120.181	.843	.362
Test * Pretest_VE	Linear	58.417	1	58.417	.410	.524
Test * Group	Linear	126.390	1	126.390	.886	.350
Error(Test)	Linear	9413.364	66	142.627		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	15908.383	1	15908.383	61.146	.000
Pretest_VE	522.636	1	522.636	2.009	.161
Group	.043	1	.043	.000	.990
Error	17171.200	66	260.170		

Regression_Radial Error

Descriptive Statistics

	Mean	Std. Deviation	N
Posttest_RE	45.5289	15.22567	66
Group	.0000	1.00766	66
Pretest_RE	66.2138	24.34873	66
All_RewP	13.8402	8.54549	66
Interest_Effort_Value	5.2247	.93545	66

Correlations

		Posttest_RE	Group	Pretest_RE	All_RewP	Interest_Effort_Value
Pearson Correlation	Posttest_RE	1.000	.050	.293	-.108	.010
	Group	.050	1.000	.048	-.021	.138
	Pretest_RE	.293	.048	1.000	-.003	.178
	All_RewP	-.108	-.021	-.003	1.000	.254
	Interest_Effort_Value	.010	.138	.178	.254	1.000
Sig. (1-tailed)	Posttest_RE	.	.344	.009	.193	.469
	Group	.344	.	.351	.435	.135
	Pretest_RE	.009	.351	.	.491	.077
	All_RewP	.193	.435	.491	.	.020
	Interest_Effort_Value	.469	.135	.077	.020	.
N	Posttest_RE	66	66	66	66	66
	Group	66	66	66	66	66
	Pretest_RE	66	66	66	66	66
	All_RewP	66	66	66	66	66
	Interest_Effort_Value	66	66	66	66	66

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Pretest_RE, Group[b]	.	Enter
2	All_RewP, Interest_Effort_Value[b]	.	Enter

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.295[a]	.087	.058	14.77712	.087	3.003	2	63	.057
2	.314[b]	.099	.040	14.91943	.012	.402	2	61	.671

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1311.471	2	655.735	3.003	.057[b]
	Residual	13756.896	63	218.363		
	Total	15068.366	65			
2	Regression	1490.413	4	372.603	1.674	.168[c]
	Residual	13577.954	61	222.589		
	Total	15068.366	65			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	33.479	5.311		6.304	.000	22.866	44.093		
	Group	.550	1.821	.036	.302	.763	-3.089	4.190	.998	1.002
	Pretest_RE	.182	.075	.291	2.415	.019	.031	.333	.998	1.002
2	(Constant)	37.710	11.103		3.397	.001	15.509	59.911		
	Group	.563	1.858	.037	.303	.763	-3.152	4.277	.977	1.023
	Pretest_RE	.184	.077	.295	2.382	.020	.030	.339	.966	1.036
	All_RewP	-.180	.225	-.101	-.804	.425	-.629	.269	.930	1.075
	Interest_Effort_Value	-.360	2.102	-.022	-.171	.864	-4.564	3.843	.886	1.129

a. Dependent Variable: Posttest_RE

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	All_RewP	-.107[b]	-.887	.378	-.112	1.000	1.000	.997
	Interest_Effort_Value	-.049[b]	-.398	.692	-.051	.952	1.051	.952

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	Group	Pretest_RE	All_RewP	Interest_Effort_Value
1	1	1.940	1.000	.03	.00	.03		
	2	1.000	1.393	.00	1.00	.00		
	3	.060	5.664	.97	.00	.97		
2	1	3.691	1.000	.00	.00	.01	.02	.00
	2	1.001	1.920	.00	.98	.00	.00	.00
	3	.222	4.078	.01	.00	.10	.84	.00
	4	.071	7.196	.07	.00	.89	.13	.08
	5	.015	15.775	.92	.02	.00	.02	.91

Regression_Bivariate Variable Error

Descriptive Statistics

	Mean	Std. Deviation	N
Posttest_VE	38.1064	11.57883	66
Group	.0000	1.00766	66
Pretest_VE	45.3089	16.13881	66
All_RewP	13.8402	8.54549	66
Interest_Effort_Value	5.2247	.93545	66

Correlations

		Posttest_VE	Group	Pretest_VE	All_RewP	Interest_Effort_Value
Pearson Correlation	Posttest_VE	1.000	.055	.177	-.058	.043
	Group	.055	1.000	.188	-.021	.138
	Pretest_VE	.177	.188	1.000	-.046	.095
	All_RewP	-.058	-.021	-.046	1.000	.254
	Interest_Effort_Value	.043	.138	.095	.254	1.000
Sig. (1-tailed)	Posttest_VE	.	.329	.078	.322	.366
	Group	.329	.	.066	.435	.135
	Pretest_VE	.078	.066	.	.356	.224
	All_RewP	.322	.435	.356	.	.020
	Interest_Effort_Value	.366	.135	.224	.020	.
N	Posttest_VE	66	66	66	66	66
	Group	66	66	66	66	66
	Pretest_VE	66	66	66	66	66
	All_RewP	66	66	66	66	66
	Interest_Effort_Value	66	66	66	66	66

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Pretest_VE, Group[b]	.	Enter
2	All_RewP, Interest_Effort_Value[b]	.	Enter

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.178[a]	.032	.001	11.57313	.032	1.032	2	63	.362
2	.189[b]	.036	-.028	11.73758	.004	.124	2	61	.884

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	276.448	2	138.224	1.032	.362[b]
	Residual	8438.057	63	133.937		
	Total	8714.505	65			
2	Regression	310.489	4	77.622	.563	.690[c]
	Residual	8404.016	61	137.771		
	Total	8714.505	65			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	32.504	4.343		7.484	.000	23.825	41.183		
	Group	.265	1.450	.023	.183	.856	-2.633	3.163	.965	1.036
	Pretest_VE	.124	.091	.172	1.365	.177	-.057	.305	.965	1.036
2	(Constant)	31.217	9.087		3.435	.001	13.046	49.388		
	Group	.199	1.484	.017	.134	.894	-2.768	3.166	.948	1.055
	Pretest_VE	.120	.092	.167	1.297	.199	-.065	.304	.956	1.046
	All_RewP	-.081	.177	-.060	-.460	.647	-.435	.272	.929	1.077
	Interest_Effort_Value	.496	1.633	.040	.304	.762	-2.769	3.761	.908	1.101

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance	VIF	Minimum Tolerance
1	All_RewP	-.050[b]	-.396	.693	-.050	.998	1.002	.963
	Interest_Effort_Value	.024[b]	.191	.850	.024	.976	1.025	.950

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	Group	Pretest_VE	All_RewP	Interest_Effort_Value
1	1	1.945	1.000	.03	.00	.03		
	2	1.000	1.395	.00	.96	.00		
	3	.055	5.941	.97	.04	.97		
2	1	3.690	1.000	.00	.00	.01	.02	.00
	2	1.003	1.918	.00	.94	.00	.00	.00
	3	.224	4.056	.01	.01	.09	.83	.00
	4	.068	7.372	.06	.02	.86	.14	.10
	5	.014	16.014	.93	.03	.04	.01	.89

Partial Correlations

Correlations

Control Variables			All_RewP	Interest_Effort_Value	Block_10_1_Change_RE	Block_10_1_Change_VE
Group	All_RewP	Correlation	1.000	.259	-.266	-.133
		Significance (2-tailed)	.	.037	.032	.291
		df	0	63	63	63
	Interest_Effort_Value	Correlation	.259	1.000	-.496	.019
		Significance (2-tailed)	.037	.	.000	.878
		df	63	0	63	63
	Block_10_1_Change_RE	Correlation	-.266	-.496	1.000	.322
		Significance (2-tailed)	.032	.000	.	.009
		df	63	63	0	63
	Block_10_1_Change_VE	Correlation	-.133	.019	.322	1.000
		Significance (2-tailed)	.291	.878	.009	.
		df	63	63	63	0