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# Self-controlled practice: Autonomy protects perceptions of competence and enhances motor learning

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ABSTRACT

*Objective:* In previous self-controlled feedback studies, it was observed that participants who could control their own feedback schedules usually use a strategy of choosing feedback after successful trials, and present superior motor learning when compared with participants who were not allowed to choose. Yoked participants of these studies, however, were thwarted not only regarding autonomy but also, presumably, regarding perceived competence, as their feedback schedules were provided randomly, regarding good or bad trials. The purpose of the present study was to examine whether self-controlled feedback schedules would have differential effects on learning if yoked participants are provided with feedback after good trials at the same rate as their self-controlled counterparts.
*Design:* Experimental study with two groups. Timing accuracy was assessed in two different experimental phases, supplemented by questionnaire data.
*Method:* Participants practiced a coincident-anticipation timing task with a self-controlled or yoked feedback schedule during practice. Participants of the self-controlled group were able to ask for feedback for two trials, after each of five 6-trial practice blocks. Yoked participants received a feedback schedule matching the self-control group schedule, according to accuracy.
*Results:* Participants asked for (self-controlled group) and received (yoked group) feedback, mainly after relatively good trials. However, participants of the self-controlled group reported greater self-efficacy at the end of practice, and performed with greater accuracy one day later, on the retention test, than the yoked group.
*Conclusions:* The findings indicate that the autonomy provided by self-controlled feedback protocols can raise learners' perceptions of competence, with positive consequences on motor learning.


Autonomy, in general, can be experienced when people act following their own beliefs and values while exercising control over some aspect of the environment. It has been linked with the satisfaction of basic psychological (Deci & Ryan, 2000, 2008) as well as biological needs (Leotti & Delgado, 2011; Leotti, Iyengar, Ochsner, 2010). In fact, individuals provided with freedom of choice have demonstrated superior results, in several domains, while performing and learning (Cordova & Lepper, 1996; Hackman & Oldham, 1976; Tafarodi, Milne, & Smith, 1999).

In the motor learning area, investigations have shown that practice schedules incorporating some form of self-control, or autonomy, can positively impact the acquisition of motor skills. Distinct learning variables as model observation (Ste-Marie, Vertes, Law, & Rymal, 2013; Wulf, Raupach, & Pfeiffer, 2005), use of assistive devices (Hartman, 2007; Wulf & Toole, 1999), order of trials during multi-task practice (Keetch & Lee, 2007; Wu & Magill, 2011), amount of practice (Post, Fairbrother, & Barros, 2011), task difficulty (Andrieux, Danna, & Thon, 2012), as well as the provision of augmented feedback (Chiviacowsky, Wulf, Medeiros, Kaefer, & Tani, 2008; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Patterson & Carter, 2010) have shown the benefits of self-controlled protocols for participants' learning, relative to externally controlled (yoked) schedules of practice.

Studies trying to investigate the reasons for the benefits of self-controlled practice for motor learning have detected, however, that besides autonomy, perceptions of competence can play an important role in this process (Chiviacowsky & Wulf, 2002, 2005; Chiviacowsky, Wulf, & Lewthwaitwe, 2012; Ste-Marie et al., 2013). Competence, along with autonomy, is considered a basic psychological need, essential for ongoing psychological growth and well-being (Deci & Ryan, 2000), and the individual's belief,

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regarding his or her competence to produce certain tasks, also defined as perceived self-efficacy (Bandura, 1977), is also linked to enhanced performance in several domains (Bandura, 1993; Feltz, Chow, & Hepler, 2008; Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008). Specifically, the degree an individual believes in his efficacy is considered to affect the quality of his cognitive, affective and decisional processes, impacting his motivation and intention to persist toward planned goals (Bandura, 2012).

In the study of Chiviacowsky and Wulf (2002), the analysis of questionnaires revealed that learners practicing in a self-controlled feedback schedule tend to ask for feedback after good trials, while yoked participants (participants who were each yoked to a participant in the self-control group regarding when feedback was or not presented) would also have preferred to receive feedback information for their best trials. Complementary analysis of feedback trials, in that study, revealed that self-controlled participants are indeed able to discriminate between more and less efficient results, with errors being lower on feedback than in no feedback trials. This situation, in general, is not found for yoked participants, who usually receive feedback randomly, regarding "good" or "bad" trials.

Subsequent research found a similar pattern of results regarding preferences for feedback after good trials in different populations and tasks (Chiviacowsky et al., 2008; Fairbrother, Laughlin, & Nguyen, 2012; Patterson & Carter, 2010), as well as reasserting the effectiveness of the learners' strategy of confirming good performance after estimated successful trials (Chiviacowsky & Wulf, 2005). More recently, participants practicing with a self-controlled feedback schedule were more directly examined regarding perceived competence and self-efficacy levels (Chiviacowsky et al., 2012). In this experiment, it was verified that depriving learners of the opportunity to feel competent, by the use of a high performance criterion for success that produced few observed "good" trials when feedback was requested, resulted in detrimental effects on their perceived competence, self-efficacy levels and motor learning. So, the opportunity to select when to receive feedback and confirm good performance seems to be critical for the benefits regularly observed for self-controlled feedback schedules on motor learning.

Together, these findings suggests that both variables, autonomy and competence, play an important role during self-controlled motor learning. This appears to be especially true when considering the effects of feedback, as feedback normally carries competence information. This observation raises the question if the benefits of practice with self-controlled feedback on motor learning would be present if yoked participants also receive feedback after their most successful practice trials. In previous studies, yoked participants typically received feedback in the same temporal order of trials asked by their self-controlled counterparts, but randomly regarding good or bad performance. Thus, the self-controlled groups probably experienced, besides autonomy, higher feelings of perceived competence or self-efficacy during practice than the yoked groups, as they were provided with a greater opportunity to confirming successful results.

As perceived competence can be considered one of the reasons for the benefits of self-controlled motor learning (e.g., Chiviacowsky et al., 2012), it seemed important to further examine the effects of autonomy provided by practice with self-controlled feedback, dissociated from potential perceived competence effects. The purpose of the present study was to test if the advantages previously observed for self-controlled groups would also be present if yoked participants are provided with a feedback schedule mirrored to their self-control counterparts regarding trial accuracy. If perceived competence is the critical condition for the observed benefits of practice with self-controlled feedback, then equalizing participants of the self-controlled and yoked groups with the same opportunity to feel competent would be expected to result in similar learning. However, if the autonomy provided by the chance to choose when to receive feedback also plays an important role in the typically seen advantages of this kind of practice, self-controlled groups would be expected to show better learning than yoked groups.

Two groups of participants practiced a novel anticipation timing task. While participants of one group (self) were able to choose when to request feedback, choosing two trials after each of 6-trial blocks, participants of the other group (yoked) received feedback in the same trials of the block as their self-control counterparts, but using a criterion of trial success. Questionnaires were completed, by all participants, at the end of the practice phase, and were used to determine participants' levels of self-efficacy, as well as their preferences for feedback after good trials. We were also interested in whether self-efficacy ratings would be able to predict learning, as observed in previous research (Chiviacowsky et al., 2012; Stevens, Anderson, O'Dwyer, & Williams, 2012).

Taking into account previous results of the literature demonstrating the motivational benefits of autonomy support for motor performance and learning (for reviews, see Lewthwaite & Wulf, 2012; Sanli, Patterson, Bray, & Lee, 2013; Wulf, 2007), we hypothesized that participants of the self-controlled group would show superior motor learning than yoked participants. Moreover, as the need for competence has been considered a basic psychological need (Deci & Ryan, 2000), we expected that participants of the self group would ask for feedback mainly after good trials, in agreement with previous literature results (Chiviacowsky & Wulf, 2002; Chiviacowsky et al., 2012; Patterson & Carter, 2010). In addition, considering that both groups would receive equal feedback regarding trial accuracy, it would be expected to find similar results in self-efficacy levels for self and yoked participants after the end of the practice phase. However, as previous findings have been suggesting the existence of an inherent reward with the exercise of control (Catania, 1975; Catania & Sagvolden, 1980; Leotti & Delgado, 2011; Tafarodi et al., 1999; Tiger, Hanley, & Hernandez, 2006), there was a possibility that participants allowed to choose when to receive feedback would present a higher level of self-efficacy than participants not provided with the possibility of choice.

## Method

### *Participants*

Twenty-eight college students (16 males, 12 females), with a mean age of 22.5 years ($SD = 3.32$), all right-handed, participated in this experiment. Calculation of the sample size was carried out, with an $\alpha$ level of 5%, effect size of .57, and a power of 80%. Participants had no prior experience with the experimental task and were not aware of the specific purpose of the study. The participants gave their informed consent and the study was approved by the university's institutional review board.

### *Apparatus and task*

The task involved anticipatory coincident timing. The Bassin anticipation timer (Model 35575, Lafayette Instruments, Lafayette, IN), an apparatus consisting of 228-cm long track with 48 light-emitting diodes (LEDs) on its surface, was used to measure temporal accuracy. The sequential illumination of the LEDs were temporally scheduled in order to create the perception of a luminous red light moving down the runway, with the (perceived) running light moving at a constant speed of 20 MPH. A barrier was placed on the top of the trackway to increase the difficulty of the task, so that the 15 lights before the target light (last one) were obscured. The task consisted of pressing a hand-held switch coincidently with the illumination of the (last) target light, with the thumb of the preferred hand. Participants had to anticipate the illumination of the target light, performing the task from a seated position, while facing the apparatus. A yellow warning light was used to indicate the initiation of the trials. It was defined to illuminate for a variable period of time (2–5 s). In order to measure temporal accuracy (absolute error, or AE), the absolute difference between the target light illumination and the press of the switch was used.

### *Procedure*

After completing the consent form, participants were randomly assigned to the self and yoked groups, yoked male-to-male and female-to-female, and introduced to the task. They were informed they should press a hand-held switch coincidently with the illumination of the target light, using the thumb of the preferred hand. In addition, they were told that pressing the switch coincidently with the target light illumination would correspond to a zero ms error.

All participants were informed that, at the end of each block of six trials, they would receive feedback on two of those trials, and that feedback would consist of the number of milliseconds the switch was pressed before or after the illumination of the target light, including error direction (e.g., −37 ms). Participants in the self-control group were additionally informed that, after each block, they would be able to choose their two preferred trials to receive the respective feedback, while participants of the yoked group were told the experimenter would choose the trials in which feedback would be provided. Different from previous self-controlled feedback studies (e.g., Chiviacowsky & Wulf, 2002; Fairbrother et al., 2012), where yoked participants receive feedback in the same order of trials as requested by participants of the self-control group, yoked participants of the present study received feedback according to accuracy of the trials, that is: if a self-control participant asked for feedback related to his first and third most accurate trials of the block, his yoked counterpart received feedback also regarding his first and third best trials of the same block.

The practice phase consisted of 30 trials, while the retention test was performed one day after the practice phase, consisting of 10 trials without feedback. Immediately after the end of the practice phase, participants of both groups completed a self-efficacy questionnaire. More specifically, they were asked to rate how confident they were that their errors would be smaller than 50, 30, and 10 ms, respectively, the next day, on a scale from 1 (“not at all”) to 10 (“very”). In addition, participants were asked to answer the Chiviacowsky and Wulf (2002) questionnaire, asking for their preferences for asking (self group) or receiving (yoked group) feedback during practice.

### *Data analysis*

Absolute error (AE) scores were calculated, and averaged across blocks of 6 (practice) or 10 (retention) trials. The practice data were analyzed in a 2 (groups) × 5 (blocks) analysis of variance (ANOVA) with repeated measures on the last factor, while an independent samples *t* test was conducted for the retention test data. *Bonferroni* post-hoc test was used for follow-up analysis. The average AEs of trials with and without feedback were calculated in order to verify whether participants of the self/yoked groups tended to ask for/receive feedback predominantly after good trials during practice. These data were analyzed in a 2 (groups) × 2 (trial type: feedback, no feedback) ANOVA with repeated measures on the last factor. Self-efficacy questions results were averaged across the three task difficulty levels (50, 30, and 10 ms) and analyzed in a one-way ANOVA. In addition, a linear regression analysis was conducted to determine whether self-efficacy predicted performance on the retention test. In order to indicate effect sizes for significant results we used partial eta-squared values ($\eta_p^2$). Alpha was set at .05 for all analysis.

## Results

### *Temporal accuracy*

#### *Practice*

During the practice phase, participants of both groups reduced their AEs (see Fig. 1, left). The *M* and *SD* values for each block of trials, during practice, were *M* 106.32 ms, *SD* 148.27; *M* 35.44 ms, *SD* 17.14; *M* 29.41 ms, *SD* 12.58; *M* 37.94 ms, *SD* 30.61; *M* 34.53 ms *SD* 21.32 for the self group, and *M* 118.91 ms, *SD* 89.51; *M* 66.75 ms, *SD* 59.66; *M* 57.05 ms, *SD* 47.58; *M* 39.82 ms, *SD* 26.59; *M* 39.07 ms *SD* 26.27 for the yoked group. The main effect of block was significant, $F(4, 104) = 8.48$, $p < .001$, $\eta_p^2 = .25$. Post hoc tests confirmed differences between block 1 and blocks 4 and 5, $p = .03$, $\eta_p^2 = .35$. There were no other differences between blocks. The main effect of group, $F(1, 26) = 1.36$, $p = .25$, and the Group × Block interaction, $F(4, 104) < 1$, were not significant.

#### *Retention*

As can be observed on Fig. 1, on the no-feedback retention test the Self group outperformed the Yoked group. The *M* and *SD* values were *M* 31.01 ms, *SD* 9.61 for the self group, and *M* 44.83 ms, *SD* 22.86 for the yoked group. The group main effect was significant, $t(26) = 2.08$, $p = .04$, $d = .78$.

### *Feedback versus no-feedback trials*

At the end of the practice phase, all participants answered questions regarding when or why they requested (self group) or preferred (yoked group) receive feedback. In the Self group, 10 out of 14 (71.4%) participants reported that they asked for feedback mostly after they thought they had a good trial. Only one participant (11.9%) indicated to have requested feedback after bad trials and three participants after good and bad trials equally. When questioned when they did not ask for feedback, most of them (12, or 85.7%) indicated to not have requested after bad trials. For the

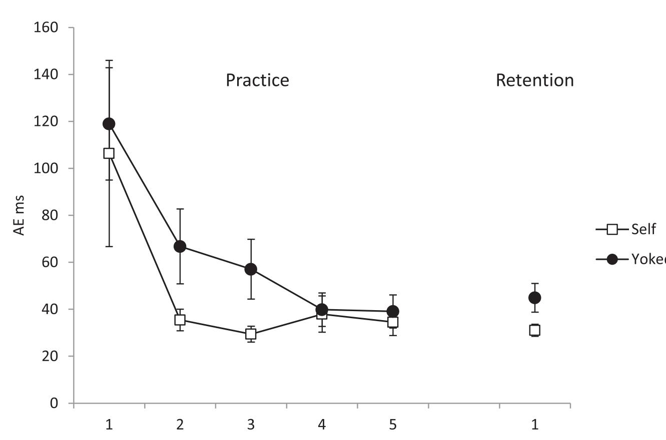


**Fig. 1.** Absolute error during practice and retention, for the self and yoked groups. Error bars indicate standard errors.

Yoked group, half of the participants reported that they received feedback after the right trials, while the other half do not. From these last participants, 4 (57.1%) of them reported they would prefer to receive feedback after good trials, while the rest of the participants checked the other 3 options ("after bad trials", "doesn't matter", "none of the previous ones").

In addition, AEs were calculated for feedback and no-feedback trials, in order to determine whether participants of the self/yoked groups actually requested/received feedback mainly after relatively successful trials, during the practice phase. For the Self group, the results showed that AEs were significantly smaller in trials for which feedback had been requested (45.68 ms) than in those for which it was not requested (50.32 ms). The same pattern was observed for participants of the Yoked group, with smaller errors in trials in which they received feedback (52.74), than in trials in which they did not receive feedback information (69.95). The main effect of trial type, $F(1, 26) = 5.76$, $p = .02$, $\eta_p^2 = .18$, was significant. There was no difference between groups, $F(1, 26) < 1$, and no interaction of group and trial type, $F(1, 26) = 1.90$, $p = .18$. Thus, participants of the Self group preferred and asked for feedback predominantly after more accurate trials, while participants of the Yoked group also received feedback mainly after their best trials.

Finally, in order to exclude possible primacy or recency effects regarding the delay between the trials for which feedback was provided and the actual feedback, we calculated for which trials, within the six trial blocks, the self-controlled and yoked groups received feedback. It was observed that both groups received a similar frequency distribution. Specifically, participants average feedback frequency on the trial blocks (1–6) was 10.71, 15.71, 18.57, 16.43, 17.86, and 20.71%, respectively, for the self-controlled group, and 10.71, 18.57, 20.71, 17.14, 17.14, and 15.71%, respectively, for the yoked group.

*Self-efficacy*

Immediately after the practice phase the participants rated how confident they were that they would be able to produce, on the next day, errors of less than 50, 30, and 10 ms, on a scale from 1–10. The three task difficulty levels were averaged to yield a single score of the self-efficacy ratings. The group effect was significant, $F(1, 26) = 4.28$, $p = .04$, $\eta_p^2 = .14$, with Self group (7.50) participants showing greater self-efficacy than Yoked group (6.17) participants.

In order to determine if self-efficacy, after the practice phase, could be considered a significant predictor of learning, a linear regression analysis was conducted, including group affiliation (dummy coded as Self = 1, Yoked = 0). The regression equation was significant, $F(1, 27) = 5.91$, $p = .008$, $R = .56$, with $\beta = -.21$, for group, and $\beta = -.45$ for self-efficacy, showing that self-efficacy significantly predicted the retention test performance, explaining 26.7% of the variance.

## Discussion

The present study was designed with the purpose of shedding further light on the reasons underlying the benefits of practice with self-controlled feedback for motor learning. Specifically, we examined the effects of autonomy provided by the chance to choose when to receive feedback, on participants' self-efficacy and motor learning levels, in relation to yoked participants matching the self-control group regarding feedback after good trials. In previous research (e.g., Chiviacowsky & Wulf, 2002; Fairbrother et al., 2012; Patterson & Carter, 2010), participants practicing with self-control of their feedback schedules usually asked for this information using a strategy of choosing feedback after successful trials and presented superior motor learning than their yoked counterparts. Yoked participants of these studies, however, were thwarted not only regarding autonomy, but also presumably regarding perceptions of competence relative to participants of the self groups, as their feedback was provided randomly regarding good or bad trials. In this way, it was still unclear if differences in learning would be found if participants of both groups receive equal feedback, regarding trial accuracy.

As expected, and in agreement with previous studies using the same task (Ali, Fawver, Kim, Fairbrother, & Janelle, 2012; Chiviacowsky et al., 2012), both groups improved performance accuracy over trial blocks, showing differences, with moderate effect sizes, between the first and final blocks of practice. The present results are also in line with those of previous self-controlled feedback studies (e.g., Chiviacowsky & Wulf, 2002, 2005; Chiviacowsky et al., 2008; Fairbrother et al., 2012; Patterson & Carter, 2010), as participants in the self group asked for feedback predominantly after the more accurate trials. As a consequence of the feedback schedule manipulation, participants of the yoked group also received feedback mainly after their most successful trials. Nevertheless, the findings showed that participants of the self group reported higher levels of self-efficacy at the end of practice and showed superior motor learning results, measured on the retention test, than participants without the chance to choose.

The learning results are in accordance with consolidated motivational psychological views showing the benefits of autonomous versus controlled regulation for goal performance, affective experiences and well-being (Deci & Ryan, 2000; Ryan & Deci, 2006). More specifically, they extend findings of self-controlled feedback studies (for reviews see Sanli et al., 2013; Wulf, 2007), emphasizing the importance of autonomy-supportive contexts of practice for the motor learning process. The observed moderate effect size is comparable to results of previous studies (see, for example, Ste-Marie et al., 2013). Importantly, in the present experiment, even when receiving feedback mainly after good trials at the same rate as their self-controlled counterparts, participants not provided with the chance to choose demonstrated lower performance on the retention test, than participants provided with choice during the learning process. So, autonomy can also be considered to play an important role in the typically seen advantages of practice with self-controlled feedback.

Interestingly, the results of the questionnaires suggest that the pattern of feedback provision used in the present study has not filled the basic psychological need for competence similarly, in both groups. As observed, only half of the yoked participants felt satisfied with the feedback schedule received, and participants of the self group reported higher levels of self-efficacy at the end of practice than participants of the yoked group. As both groups received feedback equally, mainly after successful trials, it can be inferred that perceptions of competence can be enhanced when participants experience autonomy through the opportunity of controlling their own feedback schedule. This finding provides further support for previous research indicating the existence of an inherent reward with the exercise of control. In fact, increased brain activity related to reward processing was observed when opportunities for choice are available (Leotti & Delgado, 2011). In the same vein, autonomy support has been proven to boost perceived competence/self-efficacy and learning in the academic domain. Tafarodi et al. (1999), for example, used incidental options, involving choosing among names to be used in reading comprehension assessments, and found an augmentation effect on self-perceived performance in young adults. In another experiment, Cordova and Lepper (1996) demonstrated increases in perceived competence and learning in children provided with a higher level of autonomy on an arithmetic task.

In addition, self-efficacy was found to be a predictor of motor learning. Previous findings have already confirmed self-efficacy as an important predictor of motor performance (for a review see Moritz, Feltz, Fahrbach, & Mack, 2000), and learning (Chiviacowsky et al., 2012; Stevens et al., 2012), or demonstrated a mediating role of this variable for the learning process (Lamarche, Gammage, & Adkin, 2011; Tzetzis, Votsis, & Kourtessis, 2008). Indeed, the degree to which an individual experiences feedback about successes and failures has been shown to contribute to an increase or decrease in motor learning in adults (Badami, Vaezmousavi, Wulf, & Namazizadeh, 2012; Chiviacowsky & Wulf, 2007), as well as in children (Ávila, Chiviacowsky, Wulf, & Lewthwaite, 2012; Saemi, Wulf, Varzaneh, & Zarghami, 2011). The underlying mechanisms explaining how the experience of successful performance affects motor learning still remain unclear. Individuals facing less doubt regarding their own efficacy, a situation that could have happened to a higher degree for participants of the self-controlled group, can possibly not tend to turn their attention inwardly, to "possible" deficiencies, and in this way occupy themselves with evaluative concerns (Bandura, 1982; Bandura & Wood, 1989). Inward attention is considered to lead to a kind of processing considered counterproductive to motor learning, as self-directed intrusive thoughts, probably caused by anxiety, can interfere with task-focusing thinking (Sarason, 1984; Wine, 1971; Wulf & Lewthwaite, 2010). It has also been suggested that a focus on the self, caused by worries about task performance, can lead individuals to self-regulatory processes, causing "micro-choking" episodes with attempts to control thoughts and emotions, possibly degrading learning (Wulf & Lewthwaite, 2010).

In conclusion, our results give us reasons to infer that the autonomy provided during practice with self-controlled feedback can increase the participants' perceived competence/self-efficacy, benefiting motor learning. The basic psychological need for competence seems to be better fulfilled, and participants' feelings of success increased, with direct consequences on learning, when feedback schedules of practice are linked with autonomy. The findings highlight the role of motivational influences on motor learning (Lewthwaite & Wulf, 2010, 2012). Participants of the yoked group, despite having the same opportunities of receiving feedback after relatively good trials as the self group, did not demonstrate the same psychological and learning benefits as their counterparts.

The present findings are important for theoretical and practical reasons. They extend our understanding of the learning benefits of practice with self-controlled feedback and emphasize the fact that providing learners with control of their feedback schedules can be critical for motor learning, for motivational reasons. They also provide support for the development of more effective teaching methods in learning settings. Increased confidence and higher motor learning can be expected for learners practicing in contexts that provide opportunities to experience freedom of choice. Future research could examine possible specific mechanisms mediating the relationship between autonomy, efficacy and the performance and learning of motor skills. For example, the observation of how participants of self-controlled and yoked groups use self-regulatory processes in order to cope with successful/unsuccessful results, or how affective motivational variables as task enjoyment, interest or positive and negative affect can be affected by autonomy support conditions were not examined here, and could shed further light on the reasons for the benefits of self-controlled practice for motor learning. In addition, the present study examined the learning of a simple motor task with healthy young adults. It would be fruitful to investigate if the results found can be generalized to more complex tasks, as well as different populations.

## References


Ali, A., Fawver, B., Kim, J., Fairbrother, J., & Janelle, C. M. (2012). Too much of a good thing: random practice scheduling and self-control of feedback lead to unique but not additive learning benefits. *Frontiers in Psychology, 3* (Article 503) http://dx.doi.org/10.3389/fpsyg.2012.00503.

Andriex, M., Danna, J., & Thon, B. (2012). Self-control of task difficulty during training enhances motor learning of a complex coincidence-anticipation task. *Research Quarterly for Exercise and Sport, 83*, 27–35. http://dx.doi.org/10.1080/02701367.2012.10599822.

Ávila, L. T., Chiviacowsky, S., Wulf, G., & Lewthwaite, R. (2012). Positive social-comparative feedback enhances motor learning in children. *Psychology of Sport and Exercise, 13*, 849–853. http://dx.doi.org/10.1016/j.psychsport.2012.07.001.

Badami, R., Vaezmousavi, M., Wulf, G., & Namazizadeh, M. (2012). Feedback about more accurate versus less accurate trials: differential effects on self-confidence and activation. *Research Quarterly for Exercise and Sport, 83*, 196–203. http://dx.doi.org/10.1080/02701367.2012.10599850.

Bandura, A. (1977). Self-efficacy: towards a unifying theory of behavioral change. *Psychological Review, 84*, 191–215. http://dx.doi.org/10.1037/0033-295X.84.2.191.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist, 37*, 122–147. http://dx.doi.org/10.1037/0003-066X.37.2.122.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28*, 117–148. http://dx.doi.org/10.1207/s15326985ep2802_3.

Bandura, A. (2012). On the functional properties of perceived self-efficacy revisited. *Journal of Management, 38*(1), 9–44. http://dx.doi.org/10.1177/0149206311410606.

Bandura, A., & Wood, R. (1989). Effect of perceived controllability and performance standards on self-regulation of complex decision making. *Journal of Personality and Social Psychology, 56*(5), 805. http://dx.doi.org/10.1037/0022-3514.56.5.805.

Catania, A. C. (1975). Freedom and knowledge: an experimental analysis of preference in pigeons. *Journal of Experimental Analysis of Behavior, 24*, 89–106. http://dx.doi.org/10.1901/jeab.1975.24-89.

Catania, A. C., & Sagvolden, T. (1980). Preference for free choice over forced choice in pigeons. *Journal of the Experimental Analysis of Behavior, 34*, 77–86. http://dx.doi.org/10.1901/jeab.1980.34-77.

Chiviacowsky, S., & Wulf, G. (2002). Self-controlled feedback: does it enhance learning because performers get feedback when they need it? *Research Quarterly for Exercise and Sport, 73*, 408–415. http://dx.doi.org/10.1080/02701367.2002.10609040.

Chiviacowsky, S., & Wulf, G. (2005). Self-controlled feedback is effective if it is based on the learner's performance. *Research Quarterly for Exercise and Sport, 76*, 42–48. http://dx.doi.org/10.1080/02701367.2005.10599260.

Chiviacowsky, S., & Wulf, G. (2007). Feedback after good trials enhances learning. *Research Quarterly for Exercise and Sport, 78*, 40–47. http://dx.doi.org/10.1080/02701367.2007.10599402.

Chiviacowsky, S., Wulf, G., & Lewthwaite, R. (2012). Self-controlled learning: the importance of protecting perceptions of competence. *Frontiers in Psychology, 3* (Article 458) http://dx.doi.org/10.3389/fpsyg.2012.00458.

Chiviacowsky, S., Wulf, G., Medeiros, F., Kaefer, A., & Tani, G. (2008). Learning benefits of self-controlled knowledge of results in 10-year old children. *Research Quarterly for Exercise and Sport, 79*, 405–410. http://dx.doi.org/10.1080/02701367.2008.10599505.

Cordova, D. I., & Lepper, M. R. (1996). Intrinsic motivation and the process of learning: beneficial effects of contextualization, personalization, and choice. *Journal of Educational Psychology, 88*, 715–730. http://dx.doi.org/10.1037/0022-0663.88.4.715.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 227–268. http://dx.doi.org/10.1207/S15327965PLI1104_01.

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: a macrotheory of human motivation, development, and health. *Canadian Psychology, 49*, 182–185. http://dx.doi.org/10.1037/a0012801.

Fairbrother, J. T., Laughlin, D. D., & Nguyen, T. V. (2012). Self-controlled feedback facilitates motor learning in both high and low activity individuals. *Frontiers in Psychology, 3* (Article 323) http://dx.doi.org/10.3389/fpsyg.2012.00323.

Feltz, D. L., Chow, D. M., & Hepler, T. J. (2008). Path analysis of self-efficacy and diving performance revisited. *Journal of Sport and Exercise Psychology, 30*, 401–411.

Hackman, J. R., & Oldham, G. R. (1976). Motivation through the design of work: test of a theory. *Organizational Behavior and Human Performance, 16*, 250–279. http://dx.doi.org/10.1016/0030-5073(76)90016-7.

Hartman, J. M. (2007). Self-controlled use of a perceived physical assistance device during a balancing task. *Perceptual and Motor Skills, 104*, 1005–1016. http://dx.doi.org/10.2466/pms.104.3.1005-1016.

Hutchinson, J. C., Sherman, T., Martinovic, N., & Tenenbaum, G. (2008). The effect of manipulated self-efficacy on perceived and sustained effort. *Journal of Applied Sport Psychology, 20*, 457–472. http://dx.doi.org/10.1080/10413200802351151.

Janelle, C. M., Barba, D. A., Frehlich, S. G., Tennant, L. K., & Cauraugh, J. H. (1997). Maximizing performance effectiveness through videotape replay and a self-controlled learning environment. *Research Quarterly for Exercise and Sport, 68*, 269–279. http://dx.doi.org/10.1080/02701367.1997.10608008.

Keetch, K. M., & Lee, T. D. (2007). The effect of self-regulated and experimenter-imposed practice schedules on motor learning for tasks of varying difficulty. *Research Quarterly for Exercise and Sport, 78*, 476–486. http://dx.doi.org/10.1080/02701367.2007.10599447.

Lamarche, L., Gammage, K. L., & Adkin, A. L. (2011). Can balance efficacy be manipulated using verbal feedback? *Canadian Journal of Experimental Psychology, 65*, 277–284. http://dx.doi.org/10.1037/a0024137.

Leotti, L. A., & Delgado, M. R. (2011). The inherent reward of choice. *Psychological Science, 22*, 1310–1318. http://dx.doi.org/10.1177/0956797611417005.

Leotti, L. A., Iyvengar, S. S., & Ochsner, K. N. (2010). Born to choose: the origins and value of the need for control. *Trends in Cognitive Science, 14*, 457–463. http://dx.doi.org/10.1016/j.tics.2010.08.001.

Lewthwaite, R., & Wulf, G. (2010). Grand challenge for movement science and sport psychology: embracing the social-cognitive–affective–motor nature of motor behavior. *Frontiers in Psychology, 1* (Article 42) http://dx.doi.org/10.3389/fpsyg.2010.00042.

Lewthwaite, R., & Wulf, G. (2012). Motor learning through a motivational lens. In N. J. Hodges, & A. M. Williams (Eds.), *Skill acquisition in sport: Research, theory & practice* (2nd ed.) (pp. 173–191). London: Routledge.

Moritz, S. E., Feltz, D. L., Fahrbach, K. R., & Mack, D. E. (2000). The relation of self-efficacy measures to sport performance: a meta-analytic review. *Research Quarterly for Exercise and Sport, 71*, 280–294. http://dx.doi.org/10.1080/02701367.2000.10608908.

Patterson, J. T., & Carter, M. (2010). Learner regulated knowledge of results during the acquisition of multiple timing goals. *Human Movement Science, 29*, 214–227. http://dx.doi.org/10.1016/j.humov.2009.12.003.

Post, P. G., Fairbrother, J. T., & Barros, J. A. (2011). Self-controlled amount of practice benefits learning of a motor skill. *Research Quarterly for Exercise and Sport, 82*, 474–481. http://dx.doi.org/10.1080/02701367.2011.10599780.

Ryan, R. M., & Deci, E. L. (2006). Self-Regulation and the problem of human autonomy: does psychology need choice, self-determination, and will? *Journal of Personality, 74*, 1557–1586. http://dx.doi.org/10.1111/j.1467-6494.2006.00420.x.

Saemi, E., Wulf, G., Varzaneh, A. G., & Zarghami, M. (2011). Feedback after good versus poor trials enhances learning in children. *Brazilian Journal of Physical Education and Sport, 25*, 671–679. http://dx.doi.org/10.1590/S1807-55092011000400011.

Sanli, E. A., Patterson, J. T., Bray, S. R., & Lee, T. D. (2013). Understanding self-controlled motor learning protocols through self-determination theory. *Frontiers in Psychology, 3* (Article 611) http://dx.doi.org/10.3389/fpsyg.2012.00611.

Sarason, I. G. (1984). Stress, anxiety, and cognitive interference: reactions to tests. *Journal of Personality and Social Psychology, 46*(4), 929. http://dx.doi.org/10.1037/0022-3514.46.4.929.

Ste-Marie, D. M., Vertes, K. A., Law, B., & Rymal, A. M. (2013). Learner-controlled self-observation is advantageous for motor skill acquisition. *Frontiers in Psychology, 3*. Article 556 http://dx.doi.org/10.3389/fpsyg.2012.00556.

Stevens, D., Anderson, D. I., O'Dwyer, N. J., & Williams, A. M. (2012). Does self-efficacy mediate transfer effects in the learning of easy and difficult motor skills? *Consciousness and Cognition, 21*, 1122–1128. http://dx.doi.org/10.1016/j.concog.2012.03.014.

Tafarodi, R. W., Milne, A. B., & Smith, A. J. (1999). The confidence of choice: evidence for an augmentation effect on self-perceived performance. *Personality and Social Psychology Bulletin, 25*, 1405–1416. http://dx.doi.org/10.1177/0146167299259006.

Tiger, J. H., Hanley, G. P., & Hernandez, E. (2006). An evaluation of the value of choice with preschool children. *Journal of Applied Behavior Analysis, 39*, 1–16. http://dx.doi.org/10.1901/jaba.2006.158-04.

Tzetzis, G., Votsis, E., & Kourtessis, T. (2008). The effect of different corrective feedback methods on the outcome and self confidence of young athletes. *Journal of Sports Science and Medicine, 7*, 371–378.

Wine, J. (1971). Test anxiety and direction of attention. *Psychological Bulletin, 76*, 92–104. http://dx.doi.org/10.1037/h0031332.

Wu, W. F., & Magill, R. A. (2011). Allowing learners to choose: self-controlled practice schedules for learning multiple movement patterns. *Research Quarterly for Exercise and Sport, 82*, 449–457. http://dx.doi.org/10.1080/02701367.2011.10599777.

Wulf, G. (2007). Self-controlled practice enhances motor learning: Implications for physiotherapy. *Physiotherapy, 93*, 96–101. http://dx.doi.org/10.1016/j.physio.2006.08.005.

Wulf, G., & Lewthwaite, R. (2010). Effortless motor learning? An external focus of attention enhances movement effectiveness and efficiency. In B. Bruya (Ed.), *Effortless attention: A new perspective in the cognitive science of attention and action* (pp. 75–101). Cambridge, MA: MIT Press.

Wulf, G., Raupach, M., & Pfeiffer, F. (2005). Self-controlled observational practice enhances learning. *Research Quarterly for Exercise and Sport, 76*, 107–111. http://dx.doi.org/10.1080/02701367.2005.10599266.

Wulf, G., & Toole, T. (1999). Physical assistance devices in complex motor skill learning: benefits of a self-controlled practice schedule. *Research Quarterly for Exercise and Sport, 70*, 265–272. http://dx.doi.org/10.1080/02701367.1999.10608045.