

## **Self-Controlled Feedback: Does It Enhance Learning Because Performers Get Feedback When They Need It?**

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*This paper examines whether self-controlled feedback schedules enhance learning, because they are more tailored to the performers' needs than externally controlled feedback schedules. Participants practiced a sequential timing task. One group of learners (self-control) was provided with feedback whenever they requested it, whereas another group (yoked) had no influence on the feedback schedule. The self-control group showed learning benefits on a delayed transfer test. Questionnaire results revealed that self-control learners asked for feedback primarily after good trials and yoked learners preferred to receive feedback after good trials. Analyses demonstrated that errors were lower on feedback than no-feedback trials for the self-control group but not for the yoked group. Thus, self-control participants appeared to use a strategy for requesting feedback. This might explain learning advantages of self-controlled practice.*

**Key words:** knowledge of results, motor learning, self-control, timing

**R**ecent studies have demonstrated that training protocols incorporating some form of self-control can be effective for motor skill learning. For example, Janelle and colleagues (Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Janelle, Kim, & Singer, 1995) examined learner-controlled feedback schedules. In their studies, learners could decide when they wanted to receive feedback about their movement form on a novel throwing task. When compared to participants who were each yoked to a participant in the self-control group in terms of when feedback was or was not presented, self-control group participants demonstrated clearly more effective learning. Thus, even though the feedback schedule was overall identical in both groups, providing learners the opportunity to decide when to receive

feedback was more beneficial than an externally controlled (yoked) feedback schedule. Similarly, Wulf and Toole (1999) found that allowing learners to choose when they wanted to use physical assistance devices (ski poles) in learning a ski-simulator task led to superior retention performance (without poles) relative to a yoked condition. Again, despite the fact that both groups had exactly the same pole/no-pole schedule, the self-controlled use of these devices was more effective. While in the Wulf and Toole (1999) study, as well as in the studies by Janelle et al. (1995, 1997), participants practiced individually; Wulf, Clauss, Shea, and Whitacre (2001) had self-control and yoked participants practice the ski-simulator task in dyads. Despite the potentially powerful effects of learners being able to observe each other (e.g., McCullagh, Weiss, & Ross, 1989) and perhaps compete with each other (Shea, Wulf, & Whitacre, 1999), which might have negated any effects of self-control, the self-controlled use of ski poles still resulted in more effective learning.

Thus, the self-control benefits appear to be a rather robust phenomenon. Nevertheless, it is relatively unclear what the reasons for these learning advantages are. Previous explanations are rather vague and have been adapted from the verbal or cognitive learning domain, where the effectiveness of self-regulation, or self-con-

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ontrol, has been discussed for a number of years (e.g., Carver & Scheier, 1990; Paris & Winograd, 1990; Zimmerman, 1989). For example, it has been suggested that the perception of self-control enhances learning, because it leads to a more active involvement of the learner in the learning process, which is assumed to promote a deeper processing of relevant information (McCombs, 1989; Watkins, 1984; see also Chen & Singer, 1992). Giving the learner control over the practice regimen might also be more motivating (Bandura, 1993; Boekaerts, 1996), encourage the use of self-regulation strategies (Kirschenbaum, 1984), and make performers take charge of their own learning process (e.g., Ferrari, 1996). Empirical tests of these hypotheses appear to be lacking, however, presumably because their vagueness makes them rather difficult to test. Furthermore, additional factors might be responsible for the effectiveness of self-control when it comes to learning motor skills. For example, Wulf and Toole (1999) suggested that self-controlled practice might result in more effective learning, because it encourages learners to explore different movement strategies to a greater extent than practice without self-control does.

Another possibility is that self-controlled practice conditions are more tailored to the specific needs of the learner than yoked conditions are. That is, learners might ask for physical assistance devices or feedback when they are insecure or uncertain as to how they perform. As for providing feedback, for example, learners might ask for feedback when they feel they have performed poorly (in which case the feedback could be used to get back "on track"), or they might request feedback to confirm that they performed the movement correctly. In either case, the feedback would be more useful, because self-controlled learners have the advantage to receive feedback when they actually need it, whereas this is not necessarily the case for (yoked) learners without self-control. The main purpose of the present study was to examine this hypothesis.

We used a sequential timing task that required participants to press four keys in specified goal movement times (MTs). Similar tasks have been used in numerous previous studies (e.g., Chiviackowsky, 2000; Chiviackowsky, Godinho, & Mendes, 1999; Chiviackowsky & Tani, 2000; Lai & Shea, 1998; Wulf, Lee, & Schmidt, 1994; Wulf & Schmidt, 1989). One group of learners (self-control) could request feedback about the actual MTs after each trial, while their yoked counterparts received feedback, or no feedback, respectively, on the corresponding trials.

To examine whether there was a greater congruency between performance and providing feedback for self-control learners, such that these participants, in contrast to yoked participants, received feedback when they actually needed it, we used two measures. First, we asked participants to fill out a questionnaire. Self-control par-

ticipants were asked when they had generally requested feedback (e.g., after they thought they had a "good" trial, a "bad" trial, or randomly). Yoked participants were asked whether they had received feedback after the "right" trials, and, if not, whether they would have preferred feedback mainly after good trials, bad trials, or any other, to be specified, trials. Second, we wanted to determine more objectively the nature of the relationship, if any, between performance and feedback under self-control versus yoked conditions. For this purpose, we compared performances on feedback and no-feedback trials under both conditions. If self-control participants demonstrated more effective learning but there were no subjective (questionnaire) or objective performance differences on feedback or no-feedback trials between self-control and yoked participants, it would have to be concluded that the learning advantages of self-control were not due to the practice conditions being more tailored to the performer's needs. However, if there was a subjective or objective relationship between performance and feedback in self-control, but not in yoked learners, this would support the hypothesis that this factor is critical for the benefits of self-control.

Of secondary interest in the present study was whether learning differences between self-control and yoked participants, if any, would be found for absolute and relative timing. Relative-timing performance is often viewed as a measure of the underlying movement structure, or generalized motor program, whereas absolute-timing performance is seen as a measure of the capability to parameterize an action appropriately (e.g., Schmidt, 1975, 1985). Several studies have shown that both types of movement proficiency are influenced differentially by various factors, such as feedback frequency (e.g., Lai & Shea, 1998; Wulf, Schmidt, & Deubel, 1993), bandwidth feedback (Lai & Shea, 1999), or variable versus constant practice (Lai & Shea, 1998). Therefore, we wanted to see whether self-controlled feedback would have differential effects on absolute versus relative timing. Participants practiced under self-controlled or yoked feedback conditions on 1 day, and learning was assessed in retention and transfer tests without feedback 1 day later.

## Method

### Participants

Thirty high school and university students (18 men, 12 women) with a mean age of 21.5 years volunteered to participate in this study. Informed consent was obtained from all participants. None had previous experience with the task, and all were naive as to the purpose of the experiment.

### Apparatus and Task

Participants were seated in front of a standard table on which sat a computer, color monitor, and keyboard. They were asked to keep an arm in the air, that is, without any support from the forearm or hand on the table, while executing each trial. Between trials, they could rest their arms in a convenient way. The task required participants to press four keys on the numeric keypad (2, 4, 8, and 6) in a prescribed temporal sequence and be as accurate as possible with regard to the absolute goal movement times (MTs) for each of the three movement segments (between keys). The goal MTs for the three segments were 200, 400, and 300 ms, with the total MT of 900 ms, for the acquisition and retention phases. In the transfer phase, the goal segment times were 300, 600, and 450 ms, with a total MT of 1,350 ms. The relative timing (in percent) for the three segments in all phases of the experiment were 22.2-44.4-33.3%.

### Procedure

Participants were randomly assigned to the self-control and yoked groups. They were yoked man-to-man and woman-to-woman. All participants were informed about the task goal. A graphic representation of the task, indicating the keys to be pushed and the time intervals between them, was used to explain the task. Participants in the self-control group were informed that they had to control their feedback frequency, that is, that they would not receive feedback unless they requested it. They were also instructed to request feedback only when they thought they needed it and that they would eventually have to perform the task without feedback. They were informed that the feedback, when presented, would be composed of the actual segment MTs as well as the goal segment MTs. Participants in the yoked group received the same information, with the difference that they would sometimes receive feedback and sometimes they would not.

After each trial, a square appeared on the computer screen to regulate the intertrial intervals. On trials without feedback, participants were instructed to wait for the square to disappear and start the next trial within the next 5 s. On trials followed by feedback, they were instructed to start the next trial within 5 s after the feedback had disappeared. To request feedback, participants in the self-control group were to press the "Enter" key during the time the square appeared on the screen. The experimenter demonstrated the task once to familiarize participants with the procedure and with how the feedback was presented on the computer screen.

After the practice phase, all participants were asked to complete a questionnaire and check one of several possible answers (see Table 1). Self-control participants were asked when and why they requested feedback. In

addition, they were asked when they did *not* request feedback. Yoked participants were asked whether they received feedback after the right trials, and, if not, when they would have preferred to receive feedback.

One day later, there was a retention test consisting of 10 trials on the practice task version (200-400-300 ms). In addition, participants performed 10 transfer trials on the novel task version with the same relative timing but a longer absolute duration (300-600-450 ms). No feedback was provided in either retention or transfer.

### Data Analysis

To assess absolute-timing performance, the absolute error (AE) was computed by taking the absolute difference between the overall goal MT and the actual overall MT ( $AE_{abs.tim.}$ ). Relative-timing performance was measured by computing the sum of the absolute differences between the goal proportions and the actual proportions for each segment, resulting in the absolute error in relative timing ( $AE_{rel.tim.}$ ).

To determine whether self-control participants chose feedback mainly after good or poor trials (while no such relationship would be expected for yoked participants), we calculated the average error on feedback

**Table 1.** Questions for and responses of self-control and yoked participants

Group	Number of responses
<b>Self-control group</b>	
1. When/why did you ask for feedback?	
a. ( ) mostly after you thought you had a good trial	10
b. ( ) mostly after you thought you had a bad trial	0
c. ( ) after good or bad trials equally	4
d. ( ) randomly	0
e. ( ) none of the previous ones.	1
2. When did you NOT ask for feedback:	
a. ( ) after good trials	0
b. ( ) after bad trials	11
c. ( ) none of the previous ones.	4
<b>Yoked group</b>	
1. Do you think you received KR after the right trials?	
a. ( ) Yes	4
b. ( ) No	11
2. If the answer was "No," when would you have preferred to receive feedback:	
a. ( ) after good trials	7
b. ( ) after bad trials	1
c. ( ) doesn't matter	1
d. ( ) none of the previous ones.	2

and no-feedback trials for the first and second half of the practice phase for both groups.  $AE_{abs.tim.}$  and  $AE_{rel.tim.}$  were analyzed in 2 (group)  $\times$  6 (blocks of 10 trials) analyses of variance (ANOVAs) with repeated measures on the last factor for the practice phase and in separate one-way ANOVAs for the retention and transfer tests. AEs on feedback versus no-feedback trials were analyzed in a 2 (group)  $\times$  2 (first vs. second half of practice)  $\times$  2 (trial type) ANOVAs.

## Results

### Practice

Self-control participants requested feedback after 35% of the practice trials, on average (with a range from 15 to 72% and a standard deviation of 18%). The average feedback frequency on Trial Blocks 1–6 was 44.7, 30.9, 30.7, 36.7, 30.0, and 28.0%, respectively.

**Absolute Timing Errors.**  $AE_{abs.tim.}$  for the self-control and yoked groups during practice can be seen to the left of Figure 1. Both groups decreased their average deviations from the absolute goal MTs across practice, with the self-control group tending to show somewhat lower errors. The main effect of block was significant,  $F(5, 140) = 12.16, p < .001$ , while the group main effect was not significant,  $F(1, 28) = 1.26, p > .05$ . Also, the Group  $\times$  Block interaction was not significant,  $F(5, 140) = .46, p > .05$ .

**Relative Timing Errors.** There was a general reduction in  $AE_{rel.tim.}$  across practice, although the yoked group showed a more gradual improvement in performance than the self-control group (see Figure 2). The main effect of block was again significant, with  $F(5, 140) = 10.60, p < .001$ , while the group main effect was not significant,  $F(1, 28) < 1$ . The interaction of group and block

was also significant,  $F(5, 140) = 2.45, p < .05$ . Post hoc tests (Tukey) indicated that the groups differed significantly only on the last block ( $p < .05$ ).

### Retention

**Absolute Timing Errors.** Both groups showed similar  $AE_{abs.tim.}$ , and errors were generally comparable to those reached at the end of practice (see Figure 1, middle panel). The group effect was not significant,  $F(1, 28) = .74, p > .05$ .

**Relative Timing Errors.**  $AE_{rel.tim.}$  were almost identical for both groups,  $F(1, 28) < 1$  (see Figure 2, middle panel).

### Transfer

**Absolute Timing Errors.** When transfer to a novel task version with a longer absolute goal MT (1,350 ms) was required, both groups showed an increase in  $AE_{abs.tim.}$  compared to retention. However, this performance decrement was considerably larger for the yoked group relative to the self-control group (see Figure 1, right panel). The group effect was significant,  $F(1, 28) = 5.66, p < .05$ .

**Relative Timing Errors.** Similar to retention, there were no differences between groups in  $AE_{rel.tim.}$ ,  $F(1, 28) < 1$  (see Figure 2, right panel).

### Questionnaire

The questionnaire results for the self-control (top) and yoked groups (bottom) can be seen in Table 1 (right panel). The majority of the self-control participants reported that they asked for feedback most after they thought they had a good trial (67%). In contrast, not a single participant requested feedback after a supposedly poor trial. Only 4 participants (27%) reported having asked for feedback equally after good or bad tri-

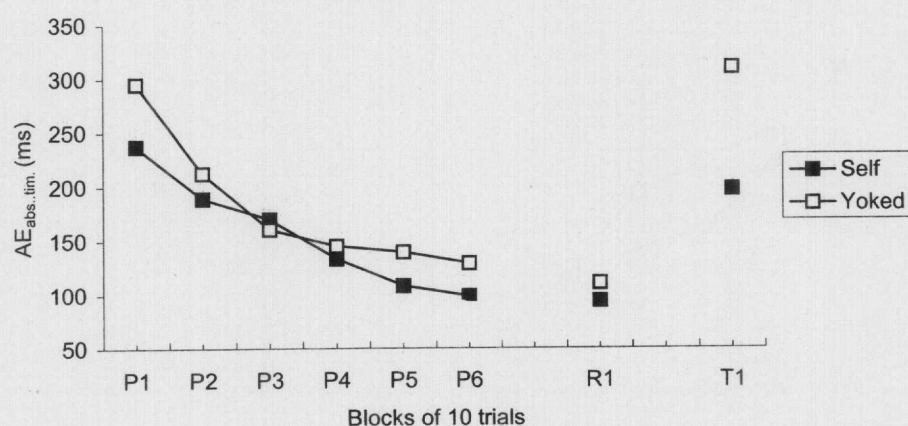


Figure 1. Absolute-timing errors ( $AE_{abs.tim.}$ ) of the self-control and yoked groups during practice (P), retention (R), and transfer (T).

als, while 1 participant (7%) indicated that he or she asked for feedback "only to compare some specific results." In response to the question when they did *not* ask for feedback, most participants (73%) said, "after bad trials." The remaining 4 participants responded "randomly," "when I knew how I was," "when I thought I wasn't good or bad," and "after every sixth trial."

In the yoked group, 11 of the 15 participants (73%) responded to the question whether they had received feedback after the right trials with "no," whereas only 4 answered "yes." Of the former 11 participants, 7 said they would have preferred feedback after good trials, whereas only 1 wanted feedback after poor trials. One participant said it didn't matter, while 2 others would have preferred feedback after all trials or after every third trial, respectively. Thus, overall the questionnaire results demonstrate a clear preference for feedback after good trials. Conversely, the majority of participants did not want to receive feedback after poor trials.

#### Feedback Frequency for "Good" Versus "Bad" Trials

To determine whether self-control participants actually asked for and received feedback more frequently after good trials than after poor trials—while such a correspondence would not be expected for yoked participants—we calculated the average  $AE_{rel.tim.}$  for feedback and no-feedback trials for the first and second half of the practice phase. For the self-control group, errors on trials with feedback were lower than on those without feedback throughout practice (first half: 191 vs. 205 ms; second half: 100 vs. 119 ms). For the yoked group, there was a trend in the opposite direction, with errors being somewhat larger on feedback trials than on no-feedback trials (first half: 256 vs. 224 ms; second half: 158 vs. 152 ms). A 2 (group)  $\times$  2 (trial type: feedback vs. no feedback)  $\times$  2 (practice half) ANOVA yielded a significant

interaction between group and trial type,  $F(1, 28) = 5.1$ ,  $p < .05$ . Post hoc tests (Tukey) indicated that the self-control group had lower errors than the yoked group on feedback trials ( $p < .05$ ), while there was no significant group difference on no-feedback trials. This confirms that self-control participants received feedback after good trials more frequently than their yoked counterparts did.

## Discussion

Although self-control has been shown to be effective for learning motor skills (Janelle et al., 1995, 1997; Wulf et al., 2001; Wulf & Toole, 1999), there have been few attempts to determine the underlying causes of this effect (for an exception, see Wulf et al., 2001). However, an understanding of the factors responsible for the effectiveness of self-control is not only important theoretically but could also lead to the development of more effective training methods in applied settings. The purpose of the present study was to examine whether a possible explanation for the benefits of self-control could be that self-controlled practice schedules are more in congruence with the learner's needs than yoked conditions, where the level of the variable being controlled is imposed on the learner in a more or less random fashion.

First, it was important to replicate the results of previous studies showing learning advantages of self-controlled feedback schedules (Janelle et al., 1995, 1997). The self-control group in the present study was more accurate in parameterizing the novel transfer task version than the yoked group, providing additional evidence for the benefits of self-control. It should be pointed out that it is not unusual for effects of a certain variable to be found in transfer but not retention (e.g.,

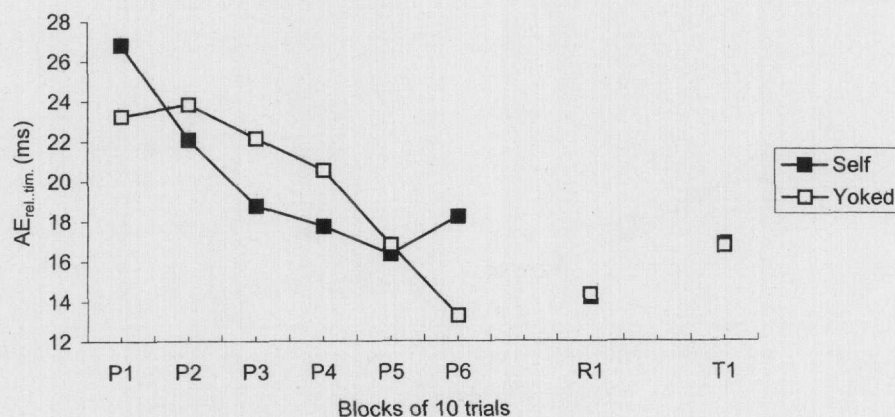


Figure 2. Relative-timing errors ( $AE_{rel.tim.}$ ) of the self-control and yoked groups during practice (P), retention (R), and transfer (T).

Lai & Shea, 1998; Wrisberg & Wulf, 1997; Wulf & Lee, 1993). It appears that the ability to generalize from one's practice experience to novel task requirements is a more sensitive measure of learning than retention of a previously practiced task. Also, in schema theory (Schmidt, 1975) terms, the effects of a strengthened schema rule, which might have developed as a function of self-controlled practice, should be stronger and more obvious, if novel parameters have to be extrapolated from past experience (e.g., Catalano & Kleiner, 1984).

It should also be noted that the sequential timing task used in the present study was considerably different from the throwing tasks used by Janelle and colleagues (1995, 1997). In their studies, feedback was provided about movement form, while accuracy information was inherent in the task and always available. In the present case, only intrinsic feedback was available for participants to determine their timing accuracy in the absence of extrinsic feedback (knowledge of results). Perhaps as a function of this, the frequency of feedback requests by the self-control participants was higher in the present study (35%) than those in the studies by Janelle et al. (1995, 1997), with 7% and 11%, respectively. At any rate, the present findings demonstrate the generalizability of self-controlled feedback advantages to tasks with different degrees of intrinsic feedback.

Our main goal in the present study, however, was to determine when and why participants, given the opportunity to do so, requested feedback. Interestingly, the interview data revealed that most learners asked for feedback only when they thought they had a good trial. Conversely, no participant asked for feedback only after supposedly poor trials. Importantly, these statements were confirmed through the analyses of feedback and no-feedback trials. Absolute-timing errors were, on average, lower on trials for which feedback was requested than they were on trials for which no feedback was requested. This not only suggests that self-control learners asked for feedback predominantly after better trials, but it also indicates they were quite effective in estimating their errors and discriminating between relatively good and poor trials. As expected, yoked learners received feedback randomly (i.e., after both good and poor trials). Indeed, the majority of yoked participants reported that they did not receive feedback after the right trials, and most of these participants said they would have preferred feedback after good trials. This trend corresponds with the self-control participants' preference and request for feedback after good trials.

These results demonstrate several important points. First, self-control learners did not request feedback randomly; rather, they had a strategy, which generally consisted in using feedback to confirm that their performance on a given trial was (more or less) on target. Second, while yoked learners also appeared to pre-

fer feedback after good trials, they did not receive feedback accordingly, as their feedback schedule was determined by their self-control partner. These findings support the hypothesis that self-controlled practice schedules are more in accordance with the performer's needs or preferences than externally controlled (yoked) schedules, which might explain the observed learning benefits. This explanation is not restricted to self-controlled feedback but could also apply, for example, to the use of assistive devices in the studies by Wulf and colleagues (Wulf et al., 2001; Wulf & Toole, 1999). In these cases, the ski poles on the ski-simulator task were, perhaps, chosen when learners felt insecure or afraid of falling, or when they wanted to try movement strategies under "safer" conditions before testing them without the physical aids. Obviously, such privileges were not available to yoked participants.

Another interesting finding is the general preference for feedback after good trials. This seems to be in contrast to theoretical views regarding the role of feedback for learning. According to the guidance hypothesis (e.g., Salmoni, Schmidt, & Walter, 1984; Schmidt, 1991a, feedback would be expected to be particularly important after poor trials (i.e., after large errors and early in practice), where it is assumed to guide the learner to the correct movement. After good trials (i.e., small errors and later in practice), feedback is viewed as being of less importance. In fact, feedback procedures, such as bandwidth feedback (e.g., Lai & Shea, 1999; Lee & Carnahan, 1990; Sherwood, 1988), are specifically designed to provide learners with feedback when they "need" it, for example, when errors exceed a certain percentage (e.g., 15%) of the goal movement time. In contrast, no feedback is provided on "good" trials, that is, when errors fall within the specified bandwidth. The assumption is that withholding feedback after relatively good trials not only indicates to learners that the movement was "correct" but also that it prevents so-called maladaptive short-term corrections (Schmidt, 1991a. Such (futile) attempts to correct for errors that are mainly caused by noise in the motor system are assumed to be counter-productive, as they hinder the development of a stable movement representation.

At least from the present findings it does not appear that such views are shared by the learners. Why they prefer feedback after good trials and not after bad trials is not clear from the present results. In fact, we do not even know whether learning would have been more effective if participants had requested feedback predominantly after poor trials. However, this seems unlikely given the fact that yoked learners received feedback after relatively poor trials to a greater extent than self-control learners. It is clear that both self-control and yoked learners were able to differentiate between "good" or "bad" trials. Thus, feedback informing them that their

performance was poor would appear to be redundant. In contrast, feedback after a good trial could be used either as information that the movement was correct or to help fine tune the movement.

The discrepancy between the effectiveness of bandwidth feedback (e.g., Lai & Shea, 1999; Lee & Carnahan, 1990; Sherwood, 1988) and the preferences for "positive" feedback found here cannot be resolved on the basis of the present results. It is possible that performances only rarely fell into the "critical" bandwidths that appear to be detrimental for the learning. However, future studies should examine more closely the function of feedback after "good" and "bad" trials.

Furthermore, there might be motivational factors responsible for the preference for feedback after successful rather than unsuccessful trials, which might also contribute to the advantages of self-controlled feedback. For example, self-control participants might have preferred feedback after good trials, because it is presumably easier to repeat a (successful) movement pattern than to change a movement pattern to correct for errors on a previous trial. This might have motivated them to try harder to produce the correct response, which should be beneficial for learning. Yoked learners, on the other hand, were not able to use feedback after good trials to confirm the correctness of a movement to the same extent as self-control learners were. This lack of feedback after presumably successful trials—which yoked participants would have preferred, as shown by the interviews—might have diminished their motivation to learn the task, relative to self-control learners.

Finally, a more minor issue we wanted to examine in the present study was whether self-control versus yoked feedback would primarily affect the learning of absolute or relative timing, or both to similar extents. Previous studies have identified a number of variables that have differential effects on these aspects of movement proficiency, such as the frequency or type of feedback, or the practice order of different task versions (e.g., Lai & Shea, 1998, 1999; Wulf et al., 1993). The present results also showed that self-control, while having no effect on relative-timing learning, was more effective for absolute-timing learning (at least when transfer to a task version with a novel absolute duration was required). This differential effect of self-controlled feedback on absolute versus relative timing might be interpreted as further evidence for the dissociation of generalized motor programs—assumed to control the relative timing of an action—and motor schemata—responsible for movement parameterization (e.g., Schmidt, 1975, 1985). However, it is also possible that no group effect was found for relative timing, because feedback was provided in form of absolute MTs. Thus, unless participants converted absolute times to relative times, there was no basis to change the relative-timing pattern.

Overall, the present findings provide new insights into the reasons underlying the learning benefits of self-controlled practice. The results show that learners based their decisions to request or not request feedback on their performance on a given trial, with preferences being given to supposedly good trials. Whatever the reasons for these preferences, it is clear that yoked learners did not have the advantage of feedback being provided as a function of their performance (or of having control over the feedback presentation). This might explain the advantages of self-controlled practice seen in this study and in previous studies. One question that would be of importance not only from a theoretical point of view but also for practical applications is whether the fact that learners are actually in control of the (feedback) schedule is critical—for example, for motivational reasons—or whether feedback provided by an "external source" such as an experimenter or coach would be equally effective if provided after the "right" trials. Questions such as these need to be addressed in future research to reach a complete understanding of the learning benefits of self-controlled practice.

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### Authors' Note

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