

SELF-CONTROLLED LEARNING OF A COMPLEX MOTOR SKILL: EFFECTS OF THE LEARNERS' PREFERENCES ON PERFORMANCE AND SELF-EFFICACY

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SUMMARY

The present study examines whether self-controlled practice enhances motor learning and self-efficacy beliefs more when it refers to an aspect of the learning situation which is preferred by the learner, rather than to an aspect which is not. Participants (N=52) practiced the forehand top spin stroke in table tennis and were randomly assigned to one of four groups. Two groups of learners (self-control) were given the option to control either a preferred practice condition (eg. schedule of video instruction) or a non-preferred practice condition (eg. variability of practice), whereas another two groups (yoked) had no influence on these practice schedules. While no group differences were found during the practice phase, both self-control groups showed learning benefits regarding the movement form on a delayed retention test. Moreover, self-control participants reported significantly higher self-efficacy beliefs than yoked participants. The results suggest that the effectiveness of self-controlled practice is independent of the learner's preferences regarding the practice situation. Future research should include cognitive and motivational variables in order to explain the learning advantages of self-controlled practice schedules.

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INTRODUCTION

Over the past two decades, self-controlled learning has emerged as an important new construct in educational, psychological and sociological research and its preconditions, components and effectiveness have been discussed intensively (Boekaerts, 1999; Boekaerts and Niemivirta, 2000; Friedrich and Mandl, 1997; Zimmerman and Schunk, 1989; Schunk and Zimmerman, 1994; Straka, 2000). With regard to the verbal or cognitive learning domain, the consensus seems to be that self-controlled learning has a beneficial effect on different aspects of the learning process (Boekaerts, 1999; Pintrich and Schrauben, 1992; Schunk and Zimmerman, 1994; Zimmerman, 1990).

What is meant by self-controlled learning? Normally, while practicing a new skill, the practice schedule is controlled by a teacher or instructor. For example, they provide instructions and feedback, decide how many trials the learner performs and select the tasks to practice. In contrast to this, self-controlled learning implies that the learner has some control over the practice situation, so that they become a more active participant in their own learning. A common conceptualisation of self-controlled learning differentiates between metacognitive, motivational and behavioural processes (Zimmerman, 1990, 1994). In terms of metacognitive processes, self-controlled

ABBREVIATIONS:

SC+	Self-control, preferred practice condition
SC-	Self-control, non-preferred practice condition
YO+	yoked, preferred practice condition
YO-	yoked, non-preferred practice condition

KEY WORDS:

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learners plan, organise, self-monitor and self-evaluate their learning at various points. Their learning is more intrinsically motivated and they report high self-efficacy beliefs (Deci and Ryan, 2000; Zimmerman, 1994). In their behavioural processes, self-controlled learners select or create environments that optimise learning: that is, they seek out advice, information, partners and places where they are most likely to learn. By doing all this, self-controlled learners use strategies which are (possibly) more congruent with their individual needs than the strategies used by a teacher or instructor. The systematic use of metacognitive, motivational and/or behavioural strategies is a key feature of most definitions of self-controlled learning. (eg. Garcia and Pintrich, 1994; Zimmerman 1990, 1994). Moreover, from a phenomenological perspective, self-controlled learners should view and feel autonomous in their learning activities (McCombs, 1989).

Recently, researchers have begun to examine the effect of self-control on motor skill learning. Most of the present studies use a simple two-group design: a self-control group, in which the subjects have control over selected aspects of the practice schedule (eg. frequency of feedback), is compared to a so called yoked group, in which the subjects are not allowed to self-determine their activities. Rather, each subject in the yoked group is matched with a subject in the self-control group and receives the same practice schedule chosen by their counterpart. Thus both groups differ from each other in the self-control variable, whereas the practice regimen is identical.

In general, these studies demonstrate that practice schedules including some form of self-control enhance the learning of motor skills, as shown by the retention results. For example, Janelle and colleagues (Janelle et al., 1997; Janelle et al., 1995) found that learners who could decide when they wanted to receive feedback demonstrated better learning of a throwing task than (yoked) learners who had no control over the provision of feedback. Wulf and Toole (1999) allowed their self-control participants to choose the use of physical assistance advice (ski poles) in learning a ski-simulator task and found superior retention performance (amplitude and frequency of movement) relative to a yoked condition. Finally, Wulf et al. (2001) examined whether the learning benefits of self-controlled practice can still be found if self-control and yoked participants practice the ski-simulator task in dyads and observe each other. Interestingly, no learning differences were found for movement features that can be easily observed (movement amplitude

and frequency), but the self-control participants were more effective than the yoked participants with respect to force onset, which is a movement feature that cannot be picked up easily through observation. This suggests that self-controlled learning in the motor domain interacts with observational learning.

Overall, it seems that, for various reasons, giving learners some control over their practice activities can enhance the effectiveness of motor learning. Also, the benefits of self-controlled practice schedules seem to be transferable to different aspects of the learning situation (feedback, use of physical aids). Nevertheless, the research is still in the beginning and the available studies are limited in several ways. Research on cognitive learning clearly shows that the effectiveness of self-controlled learning is considerably influenced by personal factors (eg. age, goal setting, beliefs, knowledge of learning strategies) as well as contextual factors (eg. task, physical and social environment; Boekaerts and Niemivirta, 2000; Friedrich and Mandl, 1997; Randi and Corno, 2000). Because of the reciprocal and dynamic interactions between (and within) these variable groups, the relative influence of the learner's preconditions depends on the learning situation and vice versa. For example, knowing of different learning strategies and how to use them is important for self-controlled learning (eg. Boekaerts, 1999; Friedrich and Mandl, 1997; Garcia and Pintrich, 1994), but their actual influence depends on the task, because some strategies are more suitable for a given task than others (the worst case would be if the learner only knows strategies which are inadequate for the task). However, previous research on self-controlled learning in the motor domain has neglected these factors and their interactions.

Another aspect of the learner-task relationship that possibly influences how effectively a self-controlled learner acts refers to the question of which component of the practice situation the participant is controlling. It is possible, however, that learners have different preferences regarding this point. For example, for a given task one learner might prefer to control the feedback schedule, whereas to another learner it might be more important to control the instruction mode. In previous studies, the role of those individual preferences was not considered; rather the learner-controlled practice condition was always determined externally (ie. by the researcher). Thus the first purpose of the present study was to examine the effect of the learners' preferences

regarding the (self)-control of practice conditions on the effectiveness of self-controlled motor learning. Participants were asked about their preferred and non-preferred self-control conditions while learning the forehand topspin stroke in table tennis and were then randomly assigned to one of four groups. During practice, two groups of learners (self-control) were given control over either a preferred condition or a non-preferred condition, whereas two groups of learners (yoked) received the same practice schedule generated in the self-control groups. Based on previous findings, we expected that the self-control groups would show superior learning compared to the yoked groups. Furthermore, it was hypothesised that giving learners control over a preferred aspect of the practice environment is more beneficial for learning than giving control over a non-preferred condition of practice. If the possibility to control a preferred versus a non-preferred practice condition is a critical variable for self-controlled motor learning, differences between the self-control groups should be found.

Among the personal factors, the learner's self-efficacy beliefs seem to play an essential role for the self-regulation of learning. Self-efficacy beliefs are personal expectations about one's capabilities to learn or perform skills at designated levels (Bandura, 1986, 1997) and research on academic learning has shown that they are related reciprocally to important aspects of self-regulation. For example, Zimmerman et al. (1992; see also Pintrich and Schrauben, 1992; Schunk and Zimmerman, 1996) found that feelings of self-efficacy are a major source of intrinsic motivation, which is seen as fundamental for an effective self-controlled learning (eg. Meece, 1994; Deci and Ryan, 2000). Because of their higher self-motivation, individuals with a strong sense of self-efficacy invest more effort, show greater persistence and use more frequently "deep-processing-strategies" than individuals with low self-efficacy. In turn, several studies have shown that giving learners control over the practice regimen (or implementing self-regulatory processes like goal setting or self-monitoring) enhance their perception of self-efficacy (Schunk, 1994; Zimmerman et al., 1996). Using a dart-throwing task, Zimmerman and Kitsantas (1996) confirmed this effect for the self-controlled learning of motor skills. However, they did not include yoked control groups. Thus it is possible that the increase of perceived self-efficacy during practice is one of the mechanisms responsible for the advantages of self-controlled learning. Therefore another purpose of this study was to examine whether the self-control and yoked conditions had different effects on the learners' self-efficacy beliefs. Self-efficacy

was measured repeatedly during practice and retention using a self-report scale. Similarly to the hypotheses mentioned above, we believed firstly that the perception of self-efficacy increases more in the self-control groups than in the yoked groups, and secondly that the highest efficacy scores would occur in the group that had control over a preferred part of the practice schedule.

In summary, using an experimental setting of self-controlled learning, we examined in this study the effects of the learners' preferences regarding the self-control manipulation on (1) motor performance during practice and retention and (2) self-efficacy beliefs.

METHOD

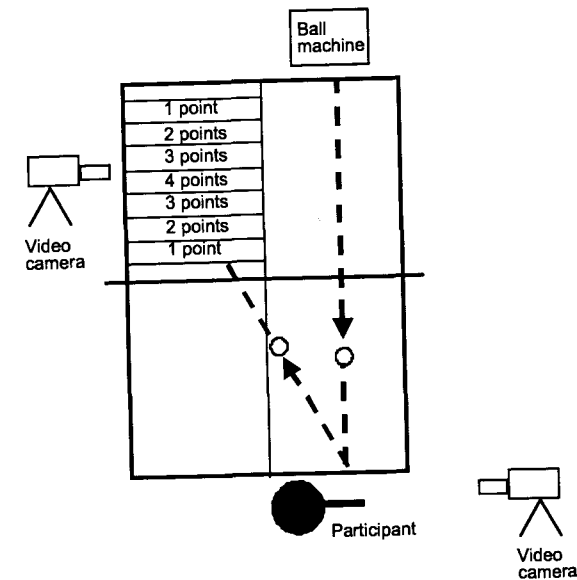
Participants

Fifty-two university students (32 male, 20 female) between the ages of 20 and 32 years participated in this study. None of them had considerable experience with the task, and all were unaware as to the purpose of the experiment. The students gave their informed consent prior to participation and were not paid for their services.

Equipment and Task

The equipment consisted of a regular-sized table-tennis table, high-quality white table tennis balls (40mm), a ball machine and a target area. The ball machine (Donic, Robopong 2040) was located on the opposite side of the table in front of the participant. The machine was set to deliver balls about every 3sec, so that the balls bounced about 20cm from the edge of the table-tennis table. On a dial from 1 to 9, the ball velocity was set at 1: that is, the ball velocity was about 15km/h. The target area was on the same side but crosscourt from the participant (see Figure 1). Made of cardboard, it consisted of seven rectangles (zones) with different colours, so that the participant could easily see the target. Each of the zones was 10cm x 65cm. If the centre of the target area was hit, then 4 points were awarded, balls landing in the zones next to this field received 3 points, and so forth. During all experimental sessions the target area was videotaped in order to measure the hitting point of the balls accurately. The video camera was positioned on the left of the table. For balls that were out of bounds or hit the net, 0 points were recorded. All participants used the same racket, an all-round composite racket with a conic handle, and preferred the shake-hands grip.

FIGURE 1: Diagram of the experimental setting.



The participants' task was to learn the forehand topspin stroke in table tennis. The topspin is an offensive stroke in which most of the strength used to perform a stroke is partly transferred into rotation of the ball forward. The racket hits the ball tangential above the middle of the ball in relation to the direction of ball flight (Gross and Huber, 1995). Participants were told that the goal was (1) to hit the ball as accurately as possible to the target area (movement accuracy) and (2) to perform the stroke technique correctly (movement form).

PROCEDURE

Before the beginning of the experiment, participants were asked to fill out a questionnaire regarding their self-control preferences while practicing the forehand topspin stroke. The questionnaire included 16 items, in which different aspects of a practice schedule were described (eg. type of movement instruction, frequency of feedback, number of practice trials). All items were introduced with the phrase "I would

like to self-control..." and the participants responded on a scale from 1 (not true) to 4 (very true). The results showed that the instruction schedule was the most preferred practice condition for self-control ($M=3.5$), whereas the option to self-determine the variability of practice, ie. the direction and length of the balls delivered by a machine or a partner, was the least preferred condition ($M=1.6$).

Based on these results, participants were randomly assigned to one of four experimental groups. Those in the SC+ group had control over a preferred practice condition: that is, they determined how often the video instruction was repeated during the practice phase. Participants in the SC- group had control over a non-preferred practice condition: that is, they were allowed to choose the variability of practice (ie. direction and length of the balls delivered by the machine). The experimenter recorded the schedules generated in the self-control groups. In contrast, participants in the yoked groups had no control over the practice situation. Rather, each in the YO+ group was yoked to a participant in the SC+ group and received the same schedule of movement instruction as their counterpart. Similarly, participants in the YO- group were matched with those in the SC- group. Thus a 2 (self-control: yes vs. no) x 2 (practice condition: preferred vs. non-preferred) design was used.

Participants were tested individually. After some preliminary instructions about the procedure, participants watched a videotaped model of a highly skilled female table tennis player. They were told to focus on the model's movement form, and it was stressed that correct form would eventually result in increased accuracy of the stroke. Altogether, participants saw 8 repetitions of the model stroke from four different perspectives, partly in slow motion. Before the beginning of the practice session, participants performed 5 "warm-up" trials in order to get used to the ball machine and a pretest consisting of 10 trials. Participants were then randomly assigned to the experimental groups as described above. The practice session consisted of 100 trials, which were divided into 10 blocks of 10 trials per block. There were short breaks (about 2min) between blocks during which the balls were collected and the ball machine was fed. During the practice phase, each participant of one of the self-control groups had the option to see the videotape again whenever he or she wanted to (SC+) or to select a block of 10 trials, in which the balls (delivered by the ball machine) varied in length and direction (SC-), respectively. Five minutes after

the last practice block, all participants performed an immediate retention test consisting of 10 trials. One day later, there was a delayed retention test also consisting of 10 trials. No augmented feedback regarding the technique or the accuracy scores was provided during practice or retention. Following delayed retention, participants were debriefed about the purpose of the experiment.

The self-efficacy scale were completed by all participants prior to each experimental phase: that is, prior to pretest (t1), first and second half of the practice session (t2, t3), early retention (t4), and late retention (t5).

Dependent Variables and Data Analysis

Motor performance and self-efficacy beliefs were used as dependent variables in this study. Performance scores included movement accuracy and movement form. A target zone recorded by a video camera was used to measure the accuracy of balls. The accuracy scores were averaged across blocks of 10 trials. For the practice phase, those scores were analyzed in a 2 (self-control) x 2 (practice condition) x 10 (block) ANOVA with repeated measures on block. The retention scores were analysed in a 2 (self-control) x 2 (practice condition) ANOVA. In addition, effect sizes were calculated in order to measure the magnitude of treatment effects independent of sample size.

Movement form was assessed on the basis of a number of criteria (eg. Gross and Huber, 1995; Grubba, 1998; Hudetz, 2000). Those criteria referred to the position, swing, stroke, point of impact and end of the stroke. Two independent raters assessed the quality of the third, fifth and eighth strokes of each block and awarded a score between 0 and 26, with the highest score indicating perfect performance. The intra-class correlation (eg. Bortz and Döring, 1995) between the scores of the two raters was 0.866, which can be interpreted as good. Therefore the scores of both raters were averaged. The form scores for the practice phase were analysed in a 2 (self-control) x 2 (practice condition) x 10 (block) repeated-measures ANOVA. For the retention tests, the form scores were analysed in a 2 (self-control) x 2 (practice condition) ANOVA. Effect sizes were calculated for significant main effects.

Self-efficacy beliefs were measured with a 10-item task-specific scale designed by the authors. All items began with the words "I am sure that I can hit at least..." followed by these phrases: (1) ... 1 of 10

balls into the target (2) ... 2 of 10 balls into the target (3) ... 3 of 10 balls into the target (3) ... 4 of 10 balls into the target, and so forth. Participants rated certainty on a scale that ranged from 1 (very uncertain) to 10 (very certain). Self-efficacy scores were calculated by summing these ratings, resulting in a possible maximum efficacy score of 100. The internal consistency of the scale ranged from ($=0.83$ [t1]) to ($=0.92$ [t5]). Similarly to the performance data, self-efficacy scores were analyzed in a 2 (self-control) x 2 (practice condition) x 5 (time of measurement) ANOVA with repeated measure on the last factor. For all analyses, the level of significance was set at an alpha level of 0.05.

RESULTS

Practice Schedules of Self-control Groups

Participants of the SC+ group requested 21 repetitions of the video instruction during the practice phase. Relating to the total number of practice blocks (10) this indicated a relative frequency of 16.15%. Participants of the SC- group used the option to self-control their practice variability 16 times, indicating a relative frequency of 12.30%. Two participants of this group decided to practice the forehand topspin stroke without varying the balls in length or direction.

Pretest

Analyses of pretest scores yielded no significant group differences regarding the performance or self-efficacy scores, all $F_s < 2$. That is, all participants had similar performance and efficacy levels prior to treatment.

Motor Performance Results

Practice - accuracy scores. The accuracy scores achieved by each of the four groups during the practice phase can be seen in Figure 2. All groups demonstrated a consistent increase in the accuracy of the strokes; the main effect of block was significant, $F(9, 432)=7.47$, $p < 0.001$. The main effects of self-control and practice condition as well as all interactions effects were not significant, all $F_s < 2$.

Practice - form scores. In terms of movement quality, the analysis yielded a significant main effect of block, $F(9, 432)=19.19$, $p < 0.001$, indicating a general improvement in form scores across practice trials (see Figure 3). In addition, the self-control groups tended to show somewhat better movement form ($M=14.11$, $SD=2.63$) than the yoked

FIGURE 2: Accuracy scores of the self-control and yoked groups during practice (P), early retention (ER), and late retention (LR).

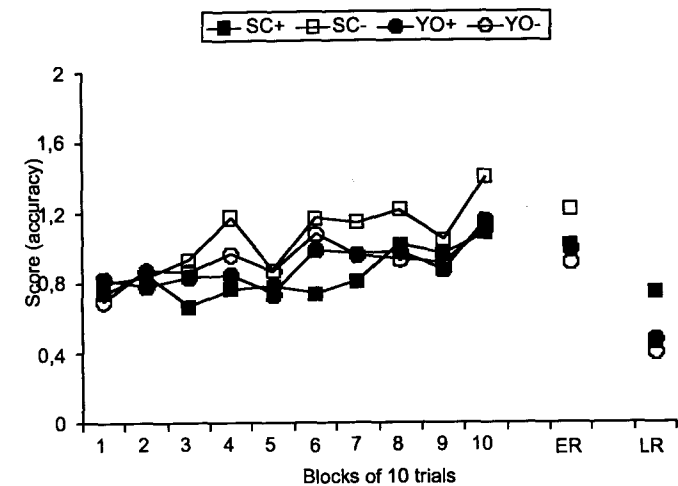
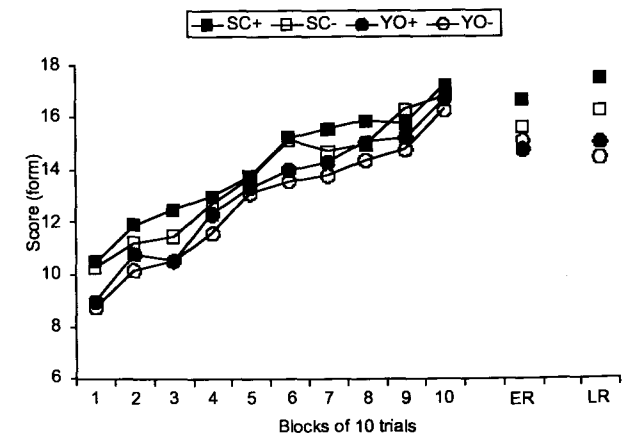


FIGURE 3: Form scores of the self-control and yoked groups during practice (P), early retention (ER), and late retention (LR).



groups ($M=12.88$, $SD=2.49$), however, the main effect of self-control fell short of significance, with $F(1, 48)=3.72$, $p=0.082$. Thus, the effect size was also small ($d=0.16$). The main effect of practice condition was not significant, $F(1, 48)=0.83$, $p>0.05$. Also, no interactions were significant.

Retention - accuracy scores. The accuracy scores of the immediate and delayed retention tests can be seen in Figure 2 (right panel). Neither during immediate retention nor during delayed retention significant main or interaction effects were found, all $F_s<1$, indicating similar performance rates for all participants.

Retention - form scores. With regard to movement form, no significant group differences were observed during immediate retention, all $F_s<2$. However, as can be seen in Figure 3, there were differences between groups in the delayed retention test. The self-control main effect was significant, $F(1, 48)=5.95$, $p<0.01$, indicating that participants in the self-control groups showed better performance ($M=16.82$, $SD=3.17$) than their yoked counterparts ($M=14.71$, $SD=3.06$). Whereas former continued to increase their form scores from the performance level they had reached during immediate retention, the yoked participants demonstrated a drop in performance, relative to the immediate retention test. The effect size d was 0.68. The main effect of practice condition was not significant, $F(1, 48)=2.25$, $p>0.05$, and neither was the interaction of self-control and practice condition, with $F(1, 48)=0.29$, $p>0.05$.

Self-efficacy results. Means and standard deviations for self-efficacy beliefs are presented in Table 1. The data showed that, across practice and retention, participants generally became more efficacious, $F(4, 192)=7.79$, $p<0.001$. However, inspection of the means indicated that participants' self-efficacy beliefs decreased briefly after performing the first half of the practice session and late retention. Results also revealed a significant main effect of self-control, $F(1, 48)=4.82$, $p<0.05$. On average over the five times of measurement, participants in the self-control groups reported higher self-efficacy beliefs ($M=46.50$, $SD=14.33$) compared with the yoked group participants ($M=41.14$, $SD=13.25$). Analogous to the performance results, the main effect of practice condition was not significant, $F(1, 48)=1.74$, $p>0.05$. Moreover, a significant self-control by time interaction was found, $F(4, 192)=4.61$, $p<0.05$, indicating differences between self-control and yoked groups

TABLE 1: Means and standard deviations for self-efficacy.

Group	Time of measurement									
	Pretest		Practice 1 (1. half)		Practice 2 (2. half)		Early retention		Late retention	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
SC+	37.0	17.1	49.3	11.3	48.8	12.1	53.0	14.7	47.5	16.1
SC-	36.0	17.6	51.9	10.1	44.3	14.2	50.5	15.8	46.6	16.9
YO+	33.4	12.2	44.0	10.2	40.3	11.5	46.9	12.5	43.6	18.0
YO-	32.9	13.4	42.3	11.0	39.8	12.0	46.4	15.5	41.7	15.9

regarding the improvement of self-efficacy. Post hoc tests of simple effects ($p<0.05$) showed that participants in the yoked groups did lower their self-efficacy beliefs after performing first half of practice (t_3) to a greater extent than the self-control participants. Furthermore, they reported significantly lower efficacy expectations prior to early and late retention (t_4 , t_5). None of the other interactions were significant.

DISCUSSION

Self-control has been shown to be effective for learning motor skills (Janelle et al., 1995, 1997; Wulf et al., 2001; Wulf and Toole, 1999), although the practice conditions opened for self-control were always specified externally (ie. by the researchers). We assumed that self-controlled learning might be more effective when it refers to an aspect of the practice situation which is important for the learner rather than to an aspect which is not.

To examine this hypothesis we compared two self-control groups that were given the option to self-control either a learner-preferred practice condition (schedule of video instruction) or a learner-non-preferred practice condition (variability of practice) during practice. Participants of two yoked groups were matched with and received the same practice schedule chosen by their self-controlled partner.

Results of the study did not support our hypothesis. Neither during practice nor in any of the retentions tests was the effect of self-controlling a preferred vs. a non-preferred practice condition significant. In other words, participants who had control over a preferred part of the practice situation did not perform the stroke more accurately or demonstrated better movement form than participants who only could self-select a non-preferred condition. However, we found significant advantages for the self-controlled groups as compared to the yoked groups. Participants who could control a part of the practice regimen (irrespective of whether it was a preferred or a non-preferred part) demonstrated better performance with regard to movement form than participants who could not. Consistent with previous findings this advantage occurred only in retention, indicating a more effective learning of the motor skill. Thus, given the experimental conditions, it was more important to give learners the opportunity to control part of the practice situation rather than to give them control over a certain practice condition, even if it might be "meaningful" to them. If one further considers that research has shown the effectiveness of self-controlled practice schedules for various aspects of the learning situation (eg. feedback, instruction, use of physical assistance devices), it seems that the benefits are not restricted on certain aspects: rather, they appear to be a result of the self-control process itself.

Furthermore, we examined the effects of self-controlled and yoked conditions on the learners' task-specific self-efficacy beliefs. Although self-efficacy has been found to influence motor skill performance and learning (eg. Bund, 2001; Moritz et al., 2000), previous research on self-controlled motor learning has not considered this factor or other psychological variables. Similar to the performance results, no differences regarding the personal efficacy were found between the two self-control groups. Instead, the main effect of self-control was significant. Participants of both self-control groups reported stronger self-efficacy expectations than did participants of the yoked groups. Particularly after failures (eg. after performing first trials of practice) the self-efficacy perceptions of the self-control participants decreased significantly less than those of the yoked participants. This supports the suggestion that learner-controlled practice schedules not only benefit the learning of motor skills, but also have positive effects on psychological states and processes. Future research on self-controlled motor learning should include those variables to confirm and extend the results of the present study.

Despite the fact that self-control benefits on motor learning appear to be a rather robust phenomenon, it is relatively unclear what the underlying causes for this effect are. Wulf and Toole (1999) suggested that self-controlled practice might result in more effective learning, because it encourages learners to try out different movement strategies to a greater extent than practice without self-control does. Relating to the concept of a "perceptual-motor-workspace" (Newell, 1991) the self-controlled use of ski poles, for example, allows the learner to explore their individual workspace more effectively. However this does not even partially explain the advantages of a learner-controlled feedback schedule, as shown by studies of Janelle and colleagues (1995, 1997). In this case, cognitive or information strategies might be more important than movement strategies.

Other explanations are rather vague and have been adapted from literature on cognitive learning, where the effectiveness of self-regulation, or self-control, has been discussed for a number of years (eg. Boekaerts et al., 2000; Straka, 2000; Zimmerman, 1990). In general, cognitive and motivational processes have been postulated. In terms of cognitive processes, 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 and promotes a deeper processing of relevant information. Several studies have demonstrated, in fact, that self-controlled learning correlates significantly with elaborative and integrative strategies, which result in a deeper understanding of the material to be learned in contrast to simple rehearsal strategies (Prosser and Millar, 1989; Entwistle et al., 1993). From a motivational point of view, it has been suggested that the effectiveness of self-controlled practice schedules might be due to an increased sense of self-efficacy and the learner's option to set goals for themselves (Deci and Ryan, 2000; Schunk and Ertmer, 2000; Zimmerman et al., 1996).

It is very likely that these processes contribute to the superiority of self-controlled learning as compared to (yoked) learning without self-control. However, if the cognitive and motivational processes work independently of each other or have a cumulative effect, self-controlled learners should demonstrate better performances than yoked learners already during practice. Actually, studies on self-controlled motor learning typically show that the beneficial effect of self-control occurs with a delay, that is in the retention test, whereas no performance differences are found during practice. In our opinion, these findings

can only be explained if one assumes an antagonistic relationship between the relevant cognitive and motivational processes.

During practice, self-controlled learners have motivational benefits compared to yoked learners. They are free to set their own goals, determine type and difficulty of the exercises and feel autonomous and self-efficacious. For this reason, they show a higher intrinsic motivation and invest more effort in learning. However, from a cognitive point of view, self-control means additional strain on the learners. Based on their knowledge of the task and of their own capabilities they have to make decisions as to their individual learning behavior. Which exercises and tasks must be chosen? When, how, and how often should one vary the learning task? When and how often should one ask for performance feedback or use physical assistance devices? Should one practice on one's own or together with others? Furthermore, self-controlled learners must monitor and evaluate the effectiveness of their activities at various points and correct them if necessary. Thus attention must be divided between the actual learning and the process of self-control (Friedrich and Mandl, 1997). The more decisions that are left to the learners, or in other words, the more degrees of freedom the self-control covers, the greater the additional cognitive strain on the learners. These antagonistic effects of cognition and motivation during self-controlled learning might result in similar performances of self-controlled and yoked learners in the practice phase of the studies.

In the retention test self-control and yoked participants perform under the same conditions. Thus there is no longer a motivational advantage of self-control. However this also means that there is no longer additional cognitive strain on the self-control learners. Now there should be a positive effect from the fact that self-controlled learners had the possibility to arrange their practice schedules in accordance with their specific needs and preferences. In a recent study, Chiviacowsky and Wulf (2002) found that self-control learners did not request feedback randomly; rather, they based their decisions on their performance on a given trial. Questionnaire data indicated that self-control learners received feedback when they actually needed it, whereas the majority of yoked learners reported that they did not receive feedback after the right trials. These findings support the hypothesis that self-controlled practice schedules are more in congruence with the learner's needs than yoked schedules, which might explain the observed retention benefits.

There are several ways to empirically test the hypothesis described here. For example, the postulated motivational advantage of self-controlled practice could be negated by giving (erroneous) failure feedback to the self-control group. According to the hypothesis, the self-controlled learners should then demonstrate poorer performances than the yoked learners during practice. Furthermore, the cognitive strain caused by working under self-control conditions could be reduced by applying an introductory training on self-controlled learning, which is an often used procedure in the research on cognitive learning (eg. Zimmerman et al., 1996). In this case it is expected that the self-control group outperform the yoked group already during practice (and not only in the retention test). At any rate, one should include another self-control group without treatment in order to prevent a confound, eg. in the former case, between self-control and feedback.

Overall, the present results, together with those of previous studies (eg. Janelle et al., 1995, 1997; Wulf and Toole, 1999; Wulf et al., 2001), provide further evidence for the benefits of self-controlled learning. In addition, they extend the previous findings in two points. Firstly, it seems that the positive effect of self-control occurs independently from the learners' preferences regarding the self-control manipulation. It is assumed that the possibility of self-control itself is more important than the aspect to which the self-control refers to. However, this needs to be confirmed by other studies with different self-control manipulations and tasks. Secondly, we showed that self-controlled learning not only has an effect on motor performance, but also on the learner's self-efficacy beliefs. This finding is in congruence with results of research on academic learning (Schunk, 1994; Schunk and Zimmerman, 1996). Because the perception of self-efficacy is a strong motivator, it is possible that the improvement of self-efficacy during practice is one of the mechanisms responsible for the learning advantages of self-controlled schedules. The delayed effect of this higher motivation is explained by the supposed antagonistic interrelation to cognitive processes. Variables such as these need to be included in future studies to reach a complete understanding of the benefits of self-controlled learning.

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