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Physical Assistance Devices in Complex Motor Skill Learning: Benefits of a Self-Controlled Practice Schedule

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This study examines the effects of a self-controlled use of physical assistance devices on learning a complex motor skill (i.e., producing slalom-type movements on a ski simulator). Physical assistance was provided by ski poles. One group of learners (self-control) was provided with the poles whenever they requested them, whereas another (yoked) group had no influence on the pole/no-pole schedule. While there were no group differences during the practice phase (Days 1 and 2), clear group differences emerged in the retention test without poles (Day 3). The self-control group produced significantly larger amplitudes than the yoked group. These results extend previous findings by showing learning advantages of the self-controlled use of physical assistance devices in complex motor skill learning.

Key words: motor learning, ski simulator

The effectiveness of self-regulation, or self-control, for learning has been discussed in the verbal or cognitive learning domain for a number of years (e.g., Carver & Scheier, 1990; Paris & Winograd, 1990; Pinard, 1992; Zimmerman, 1989). The consensus seems to be that self-controlled learning has a beneficial effect on the learning process. More recently, researchers have also begun to examine the effect of self-control on motor skill learning (Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Janelle, Kim, & Singer, 1995; Titzer Shea, & Romack, 1993). The results of these studies demonstrate that this variable can, in fact, have a decisive influence on the effectiveness of the practice schedule. For example, Janelle and colleagues (Janelle et al., 1995, 1997) showed that one way to enhance the effectiveness of feedback is to allow learners to decide when they want to receive feedback. Janelle et al. found that learners who could self-select their feedback schedule outperformed learners (yoked) in retention tests who had no control over the provision of feedback. Thus, the self-controlled feedback condition was more beneficial than an externally controlled feedback condition. Also, Titzer et al. (1993) found that a self-controlled practice schedule was as effective for learning different versions of a barrier knock-down task as random practice, and both were more effective than a blocked schedule.

Giving the learner some control over the practice regimen might promote the use of self-regulation strategies, the "processes by which people manage their own goal-directed behaviors in the relative absence of immediate external constraints" (Kirschenbaum, 1984, p. 160). Self-regulation implies that the performer takes charge of and is responsible for his or her own learning process. One factor that significantly influences how effectively the performer takes charge of learning is the perceived control (e.g., Ferrari, 1996). The perception of self-control has been shown to enhance learning, presumably because the learner's active involvement in the learning process leads to a deeper processing of relevant information (McCombs, 1989; Watkins, 1984; see also Chen & Singer, 1992). Furthermore, an important aspect

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of self-regulated learning is its goal-directedness (e.g., Boekaerts, 1996; Chen & Singer, 1992; Hardy & Nelson, 1988). Particularly if the goals are specific, short-term, and under the learner's control, goal-setting can enhance self-efficacy (i.e., one's beliefs about one's capabilities to reach a certain goal; Bandura, 1997; Zimmerman & Kitsantas, 1997). An increased sense of self-efficacy again causes the performer to set goals at a higher level of difficulty (Locke, Frederick, Bobko, & Lee, 1984), which has been found to benefit motor skill performance and learning (e.g., Boyce, 1992; Burton, 1994; Kyllo & Landers, 1995; Weinberg, 1994).

Thus, it seems that, for various reasons, giving learners some control over their practice schedule can beneficially influence on learning. Most of the self-regulation literature, however, has been concerned with verbal or cognitive learning, and evidence regarding the effectiveness of self-controlled learning of motor skills is limited (Janelle et al., 1995, 1997; Titzer et al., 1993). Yet, providing further evidence for the generalizability and robustness of this effect would not only be interesting from a theoretical point of view, but it could also have important implications for enhancing training procedures in real-world settings. Self-controlled practice situations might be particularly advantageous for learning complex skills, where self-regulation strategies should be more relevant than in simple-skill learning. The purpose of our study was to examine the generalizability of the beneficial effects of a learner-controlled practice schedule on using physical assistance devices in learning a complex motor skill.

Physical assistance is frequently used to facilitate skill acquisition in teaching complex motor skills. Examples are flotation devices to teach children how to swim, spotting belts in gymnastics, or training wheels on children's bicycles. Physical assistance is also used in physical rehabilitation settings (e.g., canes, walkers, orthotics). Assistance devices are assumed to enhance learning by providing the learner with a feel for the goal movement, reducing errors, or providing more security in potentially dangerous situations (e.g., Schmidt, 1988; 1991b). Yet, despite the frequent use of physical assistance devices, little is actually known about their effectiveness for learning. In a recent study, however, Wulf, Shea, and Whitacre (1998) found beneficial effects of physical assistance for learning to perform slalom-type movements on a ski simulator. Wulf et al. (1998) demonstrated that providing learners with ski poles not only enhanced performance during practice but was also beneficial for learning this task, as measured by a retention test. Similar to training wheels, the ski poles reduce the need to attend to certain task components, such as maintaining balance, and enable the learner to focus on the specific movements required to successfully perform the task.

Based on these findings, our goal in the present study was to examine the effects of a learner-controlled practice schedule regarding the use of physical assistance devices for learning the ski-simulator task. Two groups of participants practiced the task on two consecutive days. Whereas one group was allowed to choose when they wanted to use the poles, another (yoked) group had no control over this schedule. Learning was assessed 1 day after the end of practice in a retention test without poles. If the possibility to self-control the use of physical assistance is not essential for learning, no group differences would be expected (in retention), as both groups had the same pole/no-pole schedule. However, if the beneficial effects of self-control found in previous studies are more general in nature (i.e., some general mechanism responsible for these effects), learning advantages would also be expected for a self-controlled use of physical assistance.

Also, to examine whether the self-control and yoked conditions had different effects on the learners' fear of falling or certainty regarding their ability to reach maximum amplitudes, participants were asked to fill out a questionnaire after every other practice trial. On a scale from 1 to 9, participants indicated how afraid they were of falling, how certain they were that they wouldn't fall, and how certain they were that they would (not) reach maximum amplitudes by the end of the experiment. We wanted to assess the influence of the two practice conditions on the performers' fear of falling, because on a ski-simulator task, which, like many sport skills (e.g., bicycle riding, roller-skating, ice-skating), includes the risk of falling, one function physical assistance devices might serve is to provide the learner with a sense of security. Thus, being able to use physical assistance whenever it seems necessary might have a beneficial effect on the performance, and perhaps learning, of this task. The purpose of asking participants about their certainty regarding their ability to reach maximum amplitudes was to determine the extent participants felt they had made progress on this task and would eventually be able to reach the ultimate goal of the task (i.e., producing maximum amplitudes). It is conceivable that the self-control versus yoked conditions have different effects on participants' subjective estimates of their own performance, which could affect the learning of this task.

Method

Participants

Twenty-six students from the University of Munich participated in this experiment. Informed consent was obtained from all participants. None of them had previous experience with the task, and all were naive as to the purpose of the experiment. Participants were paid DM 24 (about $13 US) for their services.

Apparatus and Task

The ski simulator, as shown in Figure 1, is a commercially available apparatus (Trimm-Drive, Bremshey, Germany). The platform on which the participant stands can be made to move sideways on the two bowed rails by making slalom ski-type movements. Rubber belts on each side of the platform ensure that it returns to the center of the apparatus. The participant's task in this study was to move the platform of the ski simulator rhythmically to the right and the left as far as possible. The maximal amplitude of the platform in either direction from the center is 55 cm.

The platform movement was monitored by means of a potentiometer (Novotechnik, Ostfildern, Germany; P4501, 5 kΩ resistance, and .01% linearity) which was linked to the platform via a sprocket and chain assembly. One revolution of the potentiometer reflected 12.1-cm movement of the platform and resulted in a change in the digital signal from 0 to 1600. A reed switch mounted on the center of the platform and magnet-mounted on the center of the front rail provided an analog pulse each time the platform passed the center. The onset of the reed switch provided a reference for transforming the potentiometer data into platform position. The analog signals were each sampled at 50 Hz, with 12-bit resolution. This resulted in the collection of 4,500 data points per analog signal for each 90-s trial.

Procedure

Participants were randomly assigned to the self-control and yoked groups. All practiced the task on 2 consecutive days. Participants were informed that the task goal was to produce the largest possible amplitudes. No augmented feedback was given about amplitude, however, as performers could easily derive this information from intrinsic sources of feedback (visual, auditory, kinesthetic). There were seven 90-s trials on each day, with 90-s breaks between trials. Before the beginning of the actual practice phase, participants of the self-control group were informed that using poles facilitated learning the task, and they were encouraged to use the poles when they wanted. They were also informed that they would perform the task without the poles on the third day. The experimenter would hand participants the poles or take them, depending on whether the participant decided to use the poles. Also, the experimenter recorded the times during which participants used the poles on each trial. Participants of the other group were also told that using the poles facilitated learning and that they were required to perform the task without poles on the third day. However, these participants had no control over the schedule with which the poles were provided. Rather, each was yoked to a participant in the self-control group and given the poles whenever his or her counterpart in the self-control group used the poles.

Figure 1 shows a schematic of a participant without poles (top) and with poles (bottom). Each metal pole was 142 cm long and had rubber caps on both ends. When used, the poles were placed within 28 cm x 20 cm rectangles marked on the floor in front of the ski simulator;

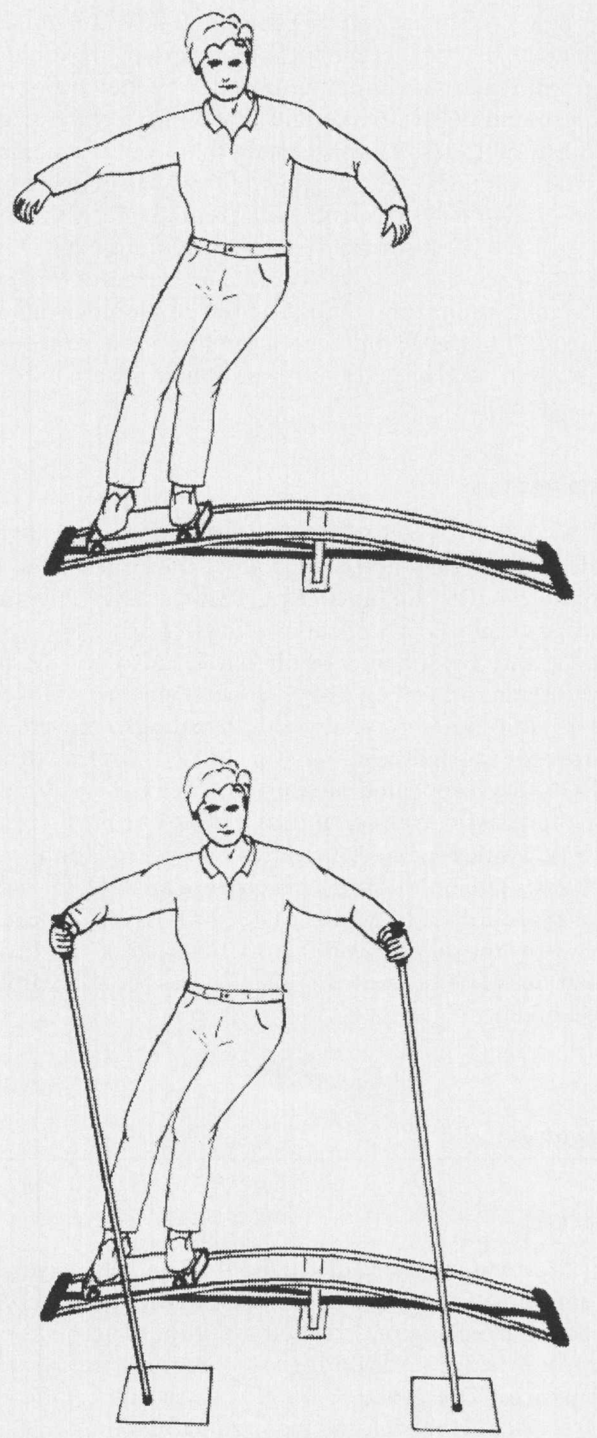

Figure 1. Schematic of a participant on the ski simulator without poles (top) and with poles (bottom).

the rectangles were 60 cm apart and 30 cm away from the ski simulator. Both poles remained in contact with the floor throughout the trial.

After the first, third, fifth, and seventh trials on each of the 2 practice days, all participants filled out a questionnaire consisting of three questions. On a scale from 1 to 9 they responded to the following: (a) How afraid are you of falling? (1 = not afraid at all; 9 = very afraid); (b) How certain are you that you won't fall? (1 = not certain at all; 9 = very certain); (c) How certain are you that you will reach maximum amplitudes by the end of the experiment? (1 = very certain that I won't reach maximum amplitudes, 9 = very certain that I will reach maximum amplitudes). The purpose of this questionnaire was to gain insights into possible differential effects the self-control or no-self-control (yoked) conditions might have on the learner's sense of security, or certainty (not) to reach maximum amplitudes, and the development across practice. On Day 3, there was a retention test, consisting of seven trials. No poles or questionnaires were used in retention.

Data Analysis

Our main dependent measure was movement amplitude, as the task goal was to produce the largest possible amplitudes. For the practice phase, we analyzed the first and last trial of each of the two days (Trials 1 and 7 on Day 1, and Trials 8 and 14 on Day 2). Also, for the delayed retention test on Day 3, the first and last trial (Trials 15 and 21) were analyzed. Accordingly, movement amplitude was analyzed in a 2 (group) x 2 (day) x 2 (trial) ANOVA with repeated measures on the last two factors for the practice phase, and in a 2 (group) x 2 (trial) ANOVA with repeated measures on trial for the retention test. The questionnaire data were analyzed in separate 2 (group) x 2 (day) x 4 (trial) ANOVAs with repeated measures on the last two factors for each of the three questions. The level of significance was set at an alpha level of .05.

Results

Practice

Movement amplitudes of the self-control and yoked groups during practice can be seen to the left of Figure 2. Both groups increased their amplitudes across the 2 days of practice, with both groups showing similar performances. The group main effect was not significant, $F(1, 23) < 1$. However, the main effect of day, $F(1, 23) = 7.55$, $p < .05$, $\omega^2 = .33$, was significant, as was the Day x Trial interaction, $F(1, 23) = 4.90$, $p < .05$, $\omega^2 = .23$, indicating greater performance gains on Day 1 compared to Day 2. The trial main effect was not significant, $F(1, 23) = 2.01$. Also, no other interactions were significant.

In assessing the performance improvements during practice, one has to take into account that movement amplitudes are influenced by using poles. As Wulf et al. (1998) have shown, the additional support provided by the poles facilitates the production of large amplitudes. Table 1 shows the average percentage of time participants used the poles on each practice trial. As can be seen, the poles were used fairly frequently at the beginning of practice (92% of the time on Trial 1), with this time being reduced to 54% by the end of Day 1. There was an increase again at the beginning of Day 2 (85%), but the time during which the poles were used was reduced to 46% on the second trial and eventually reached 25% on the last practice trial. Thus, although participants gradually decreased use of the poles, amplitudes continuously increased across practice.

The questionnaire data showed that, across practice, participants generally became less afraid of falling (Question 1) and more certain that they would not fall (Question 2; see Table 2). The responses to the third question, with an average score of 6.4 (with 5 representing "don't know"), indicated that participants, in general, were relatively uncertain about reaching maximum movement amplitudes by the end of the experiment. Interestingly, however, there were basically no differences between groups. The group main effect was not significant for any of the three questions, $F(1, 23) < 1$. However, the main effects of trial were significant for the first, $F(3, 69) = 3.8$, $p < .05$, $\omega^2 = .18$, and second question, $F(3, 69) = 5.7$, $p = .001$, $\omega^2 = .26$, and were almost significant for the third question, $F(3, 69) = 2.7$, $p = .051$. There were no significant main effects of day and no interactions for any of the questions. Thus, whether or not participants could self-select when they wanted to use the poles apparently did not affect their fear of falling or their certainty regarding achieving the task goal.

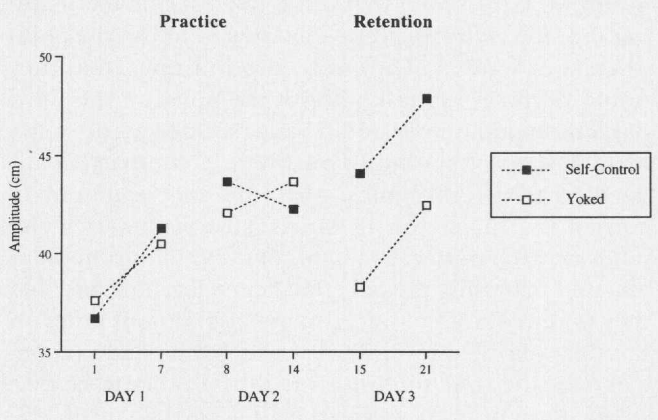

Figure 2. Movement amplitudes of the self-control and yoked groups during practice (Days 1 and 2), and in retention (Day 3).

In addition, we examined whether participants' ratings differed after trials when they used poles as compared to trials without poles. These results showed that both the self-control and yoked participants were no more afraid to fall after trials without the poles (self-control = 6.9; yoked = 6.9) than after trials with the poles (self-control = 7.0; yoked = 6.8). Also, their certainty that they wouldn't fall was not affected by using poles (self-control = 6.3; yoked = 6.4), relative to no-pole trials (self-control = 6.5; yoked = 6.5). Finally, participants were equally certain to reach maximum amplitudes, independent of whether they had used poles (self-control = 6.3; yoked = 6.3) on the previous trial (self-control = 6.6; yoked = 6.3). None of the main or interaction effects of group and pole use were significant (all $F < 1$).

Table 1. Average percentage of time the poles were used on each practice trial (in %)

Trial	1	2	3	4	5	6	7
				Day 1			
	92	92	78	58	69	61	54
				Day 2			
	85	46	35	38	53	32	25

Table 2. Responses to the three questions asked in the questionnaire on scales from 1 (not...at all) to 9 (very...) after Trials 1, 3, 5, 7, 8, 10, 12, and 14

	Day 1				Day 2			
Trial	1	3	5	7	8	10	12	14
"How afraid are you of falling?"								
Self-control	3.9	3.7	3.1	3.1	3.3	2.9	2.9	2.8
Yoked	3.9	2.9	2.5	3.2	2.8	2.9	2.5	2.6
"How certain are you that you won't fall?"								
Self-control	5.7	5.9	6.3	7.0	6.5	6.5	7.1	6.9
Yoked	5.9	6.4	6.6	6.6	6.2	6.6	6.8	6.5
"How certain are you that you will reach maximum amplitudes by the end of the experiment?"								
Self-control	6.3	6.3	6.6	6.7	6.3	7.0	6.8	7.1
Yoked	5.6	6.2	5.9	5.8	6.2	6.5	6.4	6.5

Retention

To determine the relatively permanent, or learning, effects of practice with or without a self-controlled use of poles, both groups performed a retention test on Day 3. As can be seen from Figure 2 (right panel), there were clear differences between the groups. Whereas the self-control participants continued to increase their amplitudes from the performance level they had reached by the end of the practice phase, the yoked participants demonstrated a clear drop in performance, relative to the end of practice. Although they also showed an increase in amplitude across the retention phase, by the end of Day 3 they were only at about the same performance level they had achieved by the end of Day 2 (with partial use of the poles). The main effects of both group, $F(1, 24) = 4.54$, $p < .05$, $\omega^2 = .21$, and trial were significant, $F(1, 24) = 8.79$, $p < .01$, $\omega^2 = .38$. There was no Group x Trial interaction, $F(1, 16) < 1$. Thus, allowing learners to select their own schedule of physical assistance during practice had a clearly beneficial effect on learning.

Discussion

The purpose of the present study was to examine the generalizability of previous findings showing learning advantages of learner-controlled practice conditions. Together with the previous findings that demonstrated benefits of self-controlled feedback (Janelle et al., 1995, 1997) or practice schedules (Titzer et al. 1993), the results from the present study provide converging evidence for the advantages of self-controlled learning situations. In addition, they extend the previous findings to using physical assistance in complex motor skill learning.

Interestingly, allowing learners to self-select when they wanted physical assistance did not result in performance advantages during practice. In this study, the self-control and yoked groups demonstrated similar performances. Yet, the self-controlled use of poles was clearly more effective for *learning* this task, as shown by the retention results. Thus, although there were no observable differential effects of the different treatment conditions on performance during practice, the self-controlled participants must have engaged in different information-processing activities than their yoked counterparts; otherwise, no group differences would have emerged in the no-pole retention test.

The questionnaire data indicated that the self-control condition apparently did not enhance learners' feelings of security, relative to the yoked condition. In both groups, the fear of falling was reduced from the beginning (average score = 3.9) to the end of practice (average score = 2.7) to about the same extent. (This reduction in the level of fear, by the way, occurred even when the poles were used much less frequently toward the end of practice.) The decrease in the fear of falling was accompanied by a slightly increased certainty not to fall. Yet, again, both groups showed similar scores in this regard.

Interestingly, however, although the self-control participants came, on average, much closer to the goal of producing maximum amplitudes (with an average amplitude of 48.0 cm on the last trial) than the yoked participants (42.5 cm), both groups showed similar degrees of certainty that they would reach maximum amplitudes by the end of the experiment. Thus, relative to the self-control participants, the yoked participants overestimated their ability to perform well on the retention test without poles. Perhaps participants' assessments of the progress they made on this task was based on their performance during practice. From this, they extrapolated the performance they expected to reach by the end of Day 3, and this was similar for the two groups. Whether the yoked participants' certainty to reach the task goal (maximum amplitudes) would have been diminished by their retention performance could not be determined, as no questionnaire was given on Day 3. Future studies should, therefore, include social validation procedures during or after retention tests as well. When estimating their performance at the end of the experiment, learners presumably did not take into account their information-processing efforts during practice. Obviously, these are also much harder to assess, as there is no standard against which to compare them (in contrast to the actual performance in terms of amplitude).

This raises the question of whether the information-processing activities of the self-control participants were more effective than those of the yoked participants, resulting in the learning advantages seen in retention. At present, the answer to this question can only be speculative. It seems clear, however, that learners probably did not choose to use, or not use, the poles at random; in this case, no group differences in retention should have occurred. That is, they likely had reasons for their decisions. Knowing that the task goal was to produce large amplitudes without the help of the poles, the self-control learners perhaps used the poles to try out techniques or strategies that would enable them to perform large-amplitude movements without the poles, such as the optimal "timing of forcing" (Vereijken, 1991), or weight shift from one leg to the other ("force onset;" Wulf et al., 1998) to facilitate large movement amplitudes. That is, the use of the poles may have allowed the performer to explore the "perceptual-motor workspace" (Newell, 1991) more effectively. By using the poles, performers increase their base of support which frees them from concentrating their cognitive resources on maintaining balance and gives them the opportunity for richer information processing due to the increased freedom of movement afforded by the poles. Possible movement strategies could then be tested under "real" (no-pole) conditions, and, depending on their effectiveness, be modified or revised again with the poles.

Winne (1995) also suggested that self-controlled learners are deliberate about their tactics to enhance learning, such as would be expected when, for example, they employ assisted aids (poles) to promote performance. Learners select some strategies over others based on predictions about how each is able to support progress toward the goal. These strategies imply that self-regulated learners intentionally use guided cognition to reach performance goals (Winne, 1995). Participants who had no control over the practice schedule, on the other hand, were perhaps discouraged from engaging in similar information-processing activities by the seemingly random pole/no-pole schedule. In fact, it has been argued that perceived control is a strong motivator for performance and learning (Bandura, 1997; Boekaerts, 1996). If the locus of control is removed from the performer, the task will be less intrinsically motivating (Hardy & Nelson, 1988) and presumably reduce the effort invested in learning.

It is interesting to note that the self-control participants in the present study selected a fading schedule, which has been argued to combine the benefits of guiding the learner into the right "ball park" early in practice and gradually making her or him independent from the "crutch" later in practice (e.g., Schmidt, 1991a; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). Similar observations were made by Janelle et al. (1997), whose participants also requested less feedback with increased experience on the task. Presumably due to the greater complexity of the ski-simulator task used here, as compared to the throwing tasks used by Janelle et al. (1995, 1997), however, learners used the physical aids on an average of 58% of the practice time, whereas in the studies by Janelle et al. (1995, 1997), participants requested feedback on only 7% or 11% of the trials, respectively. The gradual reduction in the use of external assistance (poles, feedback) might be seen as indicating enhanced self-efficacy. With greater success in performing the task, learners seemed to set more difficult goals (e.g., producing large amplitudes without the assistance of the poles). In fact, one aspect of Kirschenbaum's (1984, 1987; Kirschenbaum & Wittrock, 1984) model of self-regulation—besides cognition (planning, evaluation), affect (anxiety, motivation), and physiology (conditioning)—were the environmental conditions (e.g., practice schedules). Kirschenbaum viewed self-regulation as planning and considering how best to arrange one's physical environment (e.g., the use of assisted devices) to facilitate goal achievement. Similarly, Glaser (1996) pointed out that experts increasingly arrange their learning environment to enhance their performance.

Overall, the present results, together with those of pre-vious studies (Janelle et al. 1995, 1997; Titzer et al., 1993), suggest that learners can be effective in selecting practice conditions conducive to learning. Also, the benefits of self-controlled practice schedules seem to be generalizable to different aspects of the learning situation. Whether these also include, for example, the presentation of a model or different kinds of feedback, and to what extent the effectiveness of self-control is dependent on the learner's age or stage of learning, remains to be determined by future research. In addition, identifying the exact mechanisms responsible for the learning advantages of self-controlled schedules is a challenge for future work.

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