Learning Benefits of Self-Controlled Knowledge of Results in 10-Year-Old Children

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Self-controlled knowledge of results (KR) refers to a type of KR in which the learner actively chooses when to receive information about the outcome of his or her performance. That is, the learner is required to make a decision about whether or not he or she wants to receive KR after a trial. This approach differs from that used in most KR studies, in which the experimenter controls the frequency and schedule of KR delivery. Studies on self-efficacy perception (Bandura, 1977, 1993), strategies of self-regulated learning (Chen & Singer, 1992; Zimmerman & Ponz, 1986), and academic learning (Winne, 1995) have shown that learners' ability to use cognitive or behavioral strategies in a self-controlled practice context enhances their performance and learning. In the motor learning area, Janelle and collaborators (Janelle, Kim, & Singer, 1995; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997) were the first to adopt this approach by examining the effectiveness of self-controlled KR schedules. Using a novel throwing task, Janelle et al. (1997) allowed one group of learners to decide when to receive feedback about movement form. The self-control group showed clear learning advantages compared to those in the yoked group, in which each participant was yoked to one in the self-control group with regard to when KR was

or was not provided. Although the feedback schedule was identical for both groups, providing learners the opportunity to decide when they wanted to receive feedback was more beneficial than externally controlled (yoked) feedback. The self-control group also showed superior learning compared to other groups with experimenter-controlled feedback schedules (e.g., summary KR). Learning benefits have also been found for other types of self-controlled practice, such as using assistive devices (i.e., ski poles) in learning a ski simulator task (Wulf, Clauss, Shea, & Whitacre, 2001; Wulf & Toole, 1999) and observational practice for learning basketball free-throw shooting (Wulf, Raupach, & Pfeiffer, 2005).

The self-control benefits for learning appear to be a robust phenomenon. However, previous studies have exclusively used adults as participants. Thus, it is unclear whether the effects of this variable generalize to different motor development levels. An interesting question is whether children would also benefit from self-controlled practice. A potentially limiting factor in generalizing this effect to children lies in their information-processing capabilities. A number of studies suggested there are differences between children and adults in their capability to process information (e.g., Badan, Hauert, & Mounoud, 2000; Chi, 1977; Connolly, 1970, 1977; Lambert & Bard, 2005). According to Connolly (1970), changes in motor development during childhood can be attributed to two classes of variables. The first refers to "hardware" changes that occur as a function of growth. This includes such physical changes as increased strength and height as well as central nervous system changes, all of which are considered structural. The second is related to "software" changes and pertains to improvements in the capacity to use the structures. These are considered cognitive, and they occur as a consequence of developing processing-information capabilities (Connolly, 1977; Thomas, 1980).

Developmental differences in memory capacity and the use of strategies have been shown to affect processing speed, as indicated by reaction time. Various studies have demonstrated that reaction time (i.e., the time between presentation of the stimulus and the beginning of the response) decreased from 3 years of age to adolescence, indicating changes in processing speed (Chi, 1977; Badan, Hauert, & Mounoud, 2000; Lambert & Bard, 2005). That is, as the child develops, he or she can process the same information load in less time or a higher load in the same time. This change in information processing speed affects the child's ability to use information effectively and efficiently. This has been demonstrated by using various pointing tasks, for example. Ten-year-olds and adults differed in their information-processing rate (i.e., bits/s) in two-dimensional pointing (Lambert & Bard, 2005) and sequential pointing (Badan et al., 2000).

While there is a dearth of studies examining how children use feedback information, there is some indication that the ability to use KR to improve performance increases with age as well. For example, Newell and Kennedy (1978) found that precise KR degraded performance in children. More specifically, for first- (6.42 years), third- (8.50 years), fifth- (10.42 years), and ninth-grade (14.50 years) students a curvilinear relationship was found between KR and age, with imprecise and precise KR producing poor performance and the optimum precision level of KR increasing with age. In addition, Barclay and Newell (1980), who used self-paced post-KR intervals, found that 10–11-year-olds either did not use those intervals efficiently to improve their performance or took more time to process the KR. Thus, 10-year-old children clearly seem to have limitations in using relatively large amounts of information. Of course, for learning to occur, the performer needs to compare her or his intrinsic feedback with extrinsic information, or KR, so that the intrinsic feedback has a "meaning" and can be interpreted adequately in the future. This is the only way the performer can develop and refine error-detection-and-correction mechanisms with experience.

Given the limitation in children's information-processing capabilities, the benefits of self-controlled practice might be limited as well. For example, it is possible that children may be overwhelmed by having to make a decision about KR after each practice trial, which, in turn, might degrade learning. Therefore, the purpose of the present study was to examine whether the learning benefits of self-controlled KR would generalize to children. Specifically, we chose 10-year-old children representative of late childhood (6– or 7–12 years of age; Gabbard, 2000; Gallahue & Ozmun, 2002). We used a task that required the children to toss beanbags at a target. One group received KR regarding throw accuracy at their request, while another (yoked) group received KR after the same trials as their counterparts but had no control over the KR schedule. Learning was assessed in a retention test without KR 1 day after the practice phase.

An additional purpose of the present study was to determine when self-control participants would ask for KR. Chiviacowsky and Wulf (2002; see also Chiviacowsky & Wulf, 2005) found that self-control learners (adults) did not request feedback randomly; rather, they had a strategy, which generally consisted of asking for KR after "good" trials, presumably to confirm that their performance was (more or less) on target. These findings supported the view (Chiviacowsky & Wulf, 2002) that learning benefits of self-controlled practice schedules might be due to the fact that they are more in accordance with the performers' needs, or preferences, than externally controlled (yoked) schedules, which might increase participants' motivation and should have a positive influence on learning. Therefore, we wanted to determine whether 10-year-old children would also ask for KR more frequently after "good" trials as compared to "poor" trials. We surmised that this might provide clues to the reasons for the self-controlled KR benefits, if any.

Method

Participants

Twenty-six 10-year-old children (M age = 10.5 years, SD = 0.5) participated in this study. They were recruited from two classes in a public school in Pelotas, Brazil. Informed consent was obtained from the school as well as the parents/guardians and students. None of the participants had previous experience with the task, and all were naive as to the purpose of the experiment.

Apparatus and Task

The task required participants to toss beanbags (100 g), with their nondominant arm, at a target on the floor. Hand dominance was determined by asking participants which hand they used for writing. The target was placed 3 m from the participant. It was circular and had a radius of 10 cm. Concentric circles with radii of 20, 30, 40, 50, 60, 70, 80, 90, and 100 cm were drawn around the target and served as zones to assess throw accuracy. If the beanbag landed in the center of the target, 100 points were awarded. If it landed in one of the other zones or outside the circles, 90, 80, 70, 60, 50, 40, 30, 20, 10, or 0, points were recorded, respectively.

Procedure

Participants were quasirandomly assigned to the self-control and yoked groups based on the alphabetical

order of their last names. Also, participants were yoked boy-to-boy and girl-to-girl, with 8 boys and 5 girls in each group. All participants were informed about the task goal. They were instructed to toss the beanbags overhand, while standing with both feet on the ground (i.e., not to jump or walk during the toss). During the experimental phases (practice, retention), participants wore opaque swimming goggles to prevent them from viewing the target. Instructions were provided in age appropriate, clear, and simple words. Participants in the self-control group were informed that they would receive feedback only if 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. Participants in the yoked group were told that they would receive feedback sometimes and that they would eventually have to perform the task without KR. Thus, on average, the KR frequency and the spacing between KR trials were identical for the self-control and yoked groups. The only difference between groups was participants' ability to control KR delivery during practice. The target area was divided into four quadrants, so that KR could be provided in terms of the direction and distance from the target center (see Figure 1). These were indicated as "long," "short," "left," or "right." In addition, this information was qualified by the words "near" or "far" to inform the participant whether the beanbag landed near (circles 90 to 60) or far (circles 50 to 10) from the target. If it landed in circle 100, they were informed the trial was correct (bull's eye). The

experimenter verified that the children understood the feedback. The practice phase consisted of 60 trials. One day later, there was a retention test consisting of 10 trials without vision and KR.

Data Analysis

Accuracy scores were analyzed in 2 (group: self-control versus yoked) x 6 (blocks of 10 trials) analyses of variance (ANOVAs), with repeated measures on the last factor for the practice phase, and in a one-way ANOVA for the retention test. In addition, to determine whether self-control participants chose feedback mainly after relatively good or poor trials (while no such relationship would be expected for yoked participants), we calculated the accuracy scores on KR and no-KR trials for both groups (similar to Chiviacowsky & Wulf, 2002). These were analyzed in a 2 (group: self-control versus yoked) x 2 (trial type: KR vs. no KR) ANOVA with repeated measures on the last factor.

Results

Practice

On average, participants in the self-control group asked for KR after 28.3% of the practice trials. Specifically, the KR frequencies for the Blocks 1–6 of the practice phase were 30.7, 24.6, 33.9, 22.3, 26.9, and 31.5%,
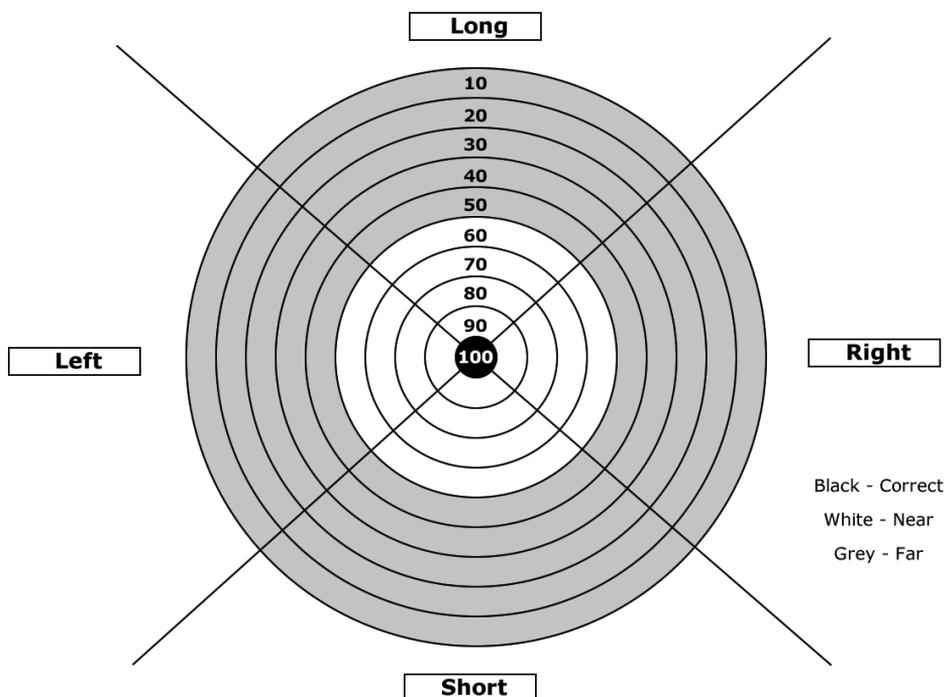

Figure 1. Schematic of the target area and zones used for providing feedback (e.g., "long, near").

respectively. Thus, participants asked for KR somewhat more frequently in the first half of practice (29.8%) than in the second half (26.9%).

Both groups increased their accuracy scores across practice blocks, with the self-control group showing higher scores than the yoked group (see Figure 2, middle). The main effect for block was significant, $F(5, 120) = 4.85$, $p < .001$, $\eta^2 = .17$, while the main effect for group just failed to reach significance, $F(1, 24) = 3.25$, $p = .08$. The interaction between group and block was not significant, $F(5, 120) < 1$. There appeared to be an advantage for the self-control group even on the first block of 10 trials. To rule out sampling error, we analyzed performances on the first trial (see Figure 2, left). The group difference on Trial 1 was not significant.

Self-control participants chose KR more after relatively good trials than after poor trials, with average accuracy scores of 38.1 on KR trials and 33.7 on no-KR trials. In contrast, accuracy scores on KR trials (23.6) versus no-KR trials (24.7) were similar for the yoked group. The interaction of group and trial type was significant, with $F(2, 24) = 5.94$, $p < .05$, $\eta^2 = .20$.

Retention

On the no-KR retention test 1 day later, the self-control group had higher accuracy scores than the yoked group (see Figure 2, right). This difference was significant, with $F(1, 24) = 4.40$, $p < .05$, $\eta^2 = .16$.

Discussion

Several studies of adults have shown that motor learning can be enhanced by allowing learners to control certain aspects of the practice conditions, such as KR, the use of physical assistance, or a video model (e.g., Chiviacowsky & Wulf, 2002; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Wulf et al., 2005; Wulf & Toole, 1999). The purpose of the present study was to examine whether the benefits of self-controlled practice—specifically, self-controlled KR—would generalize to motor learning in older children. Children differ from adults in various ways, including the ability to process information (Badan, Hauert, & Mounoud, 2000; Chi, 1977; Connolly, 1970, 1977; Fayet, Minet, & Schepens, 1993; Lambert & Bard, 2005; Thomas, 1980), and it was unclear whether children would show the same learning advantages when given the opportunity to decide how often and when they received KR.

The results of the present study indicated that learning in 10-year-olds was not hampered by the additional information-processing activities (i.e., decision making) necessary under self-control conditions. In fact, although the effect size was small (i.e., 0.2; Cohen, 1969), learning was significantly enhanced. The present findings replicate those of previous studies with adult participants (e.g., Chiviacowsky & Wulf, 2002; Janelle et al., 1995, 1997) in various ways. First, self-control participants asked for KR on a relatively small portion of trials (28.3%), and they tended to choose a "fading" schedule, that is, they requested less KR in the second half of practice (26.9%) compared to the first half (29.8%). In previous studies, the percentage of KR trials was also relatively small (i.e., 35% in Chiviacowsky & Wulf, 2002; 7% in Janelle et al., 1995; 11% in Janelle et al., 1997). In addition, participants asked for KR less frequently later in practice. These findings correspond with experimental findings showing that reduced KR frequencies and, in particular, fading schedules are often more effective for learning than fre-
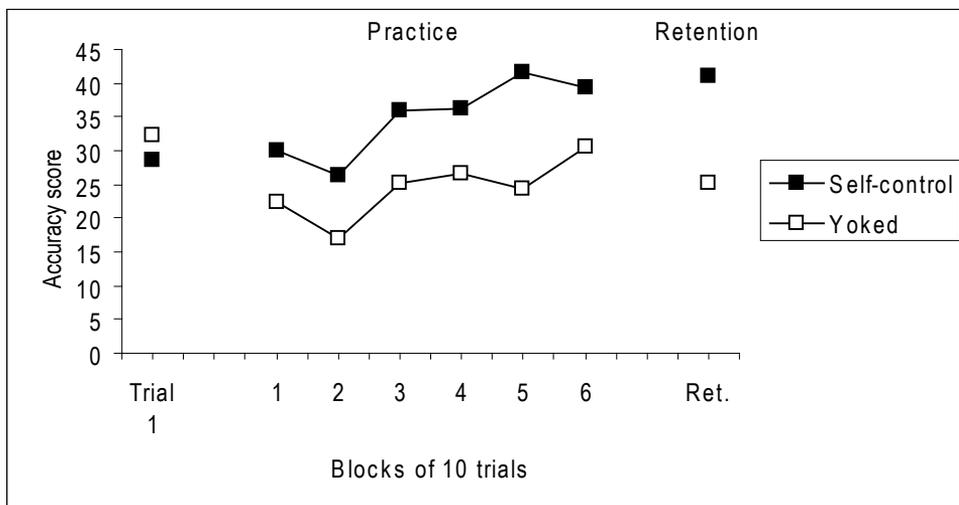

Figure 2. Accuracy scores of the self-control and yoked groups on Trial 1 (right), during practice (middle), and on the retention test (right).

quent KR (e.g., Winstein & Schmidt, 1990; for reviews, see Schmidt, 1991; Wulf & Shea, 2004).

Second, similar to adults, the 10-year-old children in the present study demonstrated more effective learning when they were allowed to decide when to receive KR, compared to those who did not have that opportunity. As expected, there were no group differences early in practice, although the self-control group showed some performance advantages (i.e., higher accuracy scores) during most of the practice phase. In most previous studies, there were no significant differences between self-control and yoked groups during practice (e.g., Chiviacowsky & Wulf, 2002; Janelle et al., 1995, 1997; Wulf, Raupach, & Pfeiffer, 2005; Wulf & Toole, 1999). It is possible that the additional information-processing activities necessary under self-control conditions, such as subjective estimations of one's errors to determine whether or not to request KR, cancel out any performance advantages of motivational effects. Most importantly, on the retention test, when participants received no KR (and no decision-making processes were necessary), the self-control group showed superior learning relative to the yoked group.

Third, as in the Chiviacowsky and Wulf (2002) study, self-control participants requested KR more frequently after relatively successful trials, compared to poor trials, as indicated by the higher accuracy on KR relative to no-KR trials. The interviews (with adults) conducted by Chiviacowsky and Wulf (2002) indicated that participants—both self-control and yoked—clearly preferred to receive KR after good trials. Interestingly, the adult participants in their study and the children in the present study also chose KR more often after good trials. Thus, self-controlled learners appeared to ask for KR primarily to confirm they were on the "right track." It also indicates that learners—both adults and 10-year-old children—had a relatively good "feel" for how they performed on a given trial.

How can the learning advantages of self-controlled practice be explained? Chiviacowsky and Wulf (2002) argued that one advantage of self-controlled practice might be that it is tailored to the learner's needs. Their findings supported this idea by showing a greater correspondence between the performer's desire for and the delivery of feedback under self-controlled relative to yoked conditions, as participants received KR more frequently after good than after poor trials. The present results, which showed the children also asked for KR predominantly after relatively good trials, are in line with those findings. Interestingly, Chiviacowsky and Wulf (2007) found that KR was more effective (for adult learners) when provided after relatively good, as opposed to relatively poor, trials. They argued that receiving KR after good trials might create a greater success experience for the learner than KR after poor trials. This might increase motivation and, in turn, enhance learning. Thus, together with new findings, which showed greater performance gains when

participants received positive feedback compared to a control condition (West, Bagwell, & Dark-Freudeman, 2005), as well as findings indicating that certain brain areas respond more strongly to positive feedback than to negative feedback (Nieuwenhuis, Slagter, Alting von Geusau, Heslenfeld, & Holroyd, 2005), there seems to be evidence that the main benefit of self-controlled feedback may be motivational.

Overall, the results of the present study demonstrate that the advantage of giving learners the opportunity to decide when to receive KR generalizes to older children. These learning benefits seem to be attributable to motivational factors. These findings may have important implications for practical settings in which instructors typically give feedback when they assume the child needs it most (i.e., mainly after unsuccessful trials) to avoid errors and guide the child to the correct movement pattern. Because the children in the present study chose KR mainly after good trials, it suggests they used intrinsic feedback to evaluate their performance and that KR after poor trials might be redundant. Giving the child the opportunity to ask for feedback, or providing feedback after successful movements, may be a more effective way to facilitate learning. Future studies are necessary to determine whether the present findings generalize to children of other age groups, in particular younger children, or whether there are developmental differences. Furthermore, different types of feedback could be examined. In the present study, feedback referred to accuracy of the movement outcome (i.e., KR). In many real-life tasks, this type of feedback is inherent in the task (e.g., when hitting a golf ball, throwing a basketball, or performing a high jump). As such, the task in the present study, was somewhat artificial. Thus, an interesting question for future studies would be to examine whether the effects of self-controlled feedback generalize to feedback information about movement form (i.e., knowledge of performance). Another fruitful direction for future research might be to examine the generalizability of other self-controlled practice schedules to children, such as those related to observational practice (Wulf et al., 2005), task order (Titzer, Shea, & Romack, 1993), or physical assistance (e.g., Wulf & Toole, 1999). Given the robustness of self-control benefits, which have been demonstrated for a variety of factors, tasks, and populations, it appears there might be a relatively broad potential for enhancing motor learning in different settings.

References

Badan, M., Hauert, C. A., & Mounoud, P. (2000). Sequential pointing in children and adults. *Journal of Experimental Child Psychology, 75*, 43–69.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84,* 191–215.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28,* 117–148.

Barclay, C. R., & Newell, K. M. (1980). Children's processing of information in motor skill acquisition. *Journal of Experimental Child Psychology, 30,* 98-108.

Chen, D., & Singer, R. N. (1992). Self-regulation and cognitive strategies in sport participation. *International Journal of Sport Psychology, 23,* 277–300.

Chi, M. T. H. (1977). Age differences in memory span. *Journal of Experimental Child Psychology, 23,* 266–281.

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

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

Chiviacowsky, S., & Wulf, G. (2007). Feedback after good trials enhances learning. *Research Quarterly for Exercise and Sport, 78,* 40–47.

Cohen, J. (1969). *Statistical power analysis for the behavioral sciences* (2nd ed.). New York: Academic press.

Connolly, K. (1970). *Mechanisms of motor skill development.* London: Academic Press.

Connolly, K. (1977). The nature of motor skill development. *Journal of Human Movement Studies, 3,* 128–143.

Fayet, C., Minet, M., & Schepens, N. (1993). Children's and adults' learning of visuomanual coordination: Role of ongoing visual feedback and spatial errors as a function of age. *Perceptual and Motor Skills,* 77**,** 659–669.

Gallahue, D. L., & Ozmun, J. C. (2002). *Understanding motor development: Infants, children, adolescents, adults.* New York: McGraw-Hill.

Gabbard, C. P. (2000). *Lifelong motor development.* Boston: Allyn & Bacon.

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

Janelle, C. M., Kim, J., & Singer, R. N. (1995). Subject-controlled performance feedback and learning of a closed motor skill. *Perceptual and Motor Skills, 81,* 627–634.

Lambert, J., & Bard, C. (2005). Acquisition of visuomanual skills and improvement of information processing capacities in 6- to 10-year-old children performing a 2D pointing task. *Neuroscience Letters, 377,* 1–6.

Newell, K. M., & Kennedy, J. A. (1978). Knowledge of results and children's motor learning. *Developmental Psychology, 14,* 531–536.

Nieuwenhuis, S., Slagter, H. A., Alting von Geusau, N. J., Heslenfeld, D. J., & Holroyd, C. B. (2005). Knowing good from bad: Differential activation of human cortical areas by positive and negative outcomes. *European Journal of Neuroscience, 21,* 3161–3168.

Schmidt, R. A. (1991). Frequent augmented feedback can degrade learning: Evidence and interpretations. In J. Requin & G. E. Stelmach (Eds.), *Tutorials in motor neuroscience* (pp. 59–75). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Thomas, J. R. (1980). Acquisition of motor skills: Information processing differences between children and adults. *Research Quarterly for Exercise and Sport, 51,* 158–173.

Titzer, R., Shea, J. B., & Romack, J. (1993). The effect of learner control on the acquisition and retention of a motor task. *Journal of Sport & Exercise Psychology, 15*(Suppl.), S84.

West, R. L., Bagwell, D. K., & Dark-Freudeman, A. (2005). Memory and goal setting: The response of older and younger adults to positive and objective feedback. *Psychology and Aging, 20,* 195–201.

Winne, P. H. (1995). Inherent details of self-regulated learning. *Educational Psychologist, 30,* 173–187.

Winstein, C. J., & Schmidt, R. A. (1990). Reduced frequency of knowledge of results enhances motor skill learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 677–691.

Wulf, G., Clauss, A., Shea, C. H., & Whitacre, C. (2001). Benefits of self-control in dyad practice. *Research* Quarterly *for Exercise and Sport, 72,* 299–303.

Wulf, G., Raupach, M., & Pfeiffer, F. (2005). Self-controlled observational practice enhances learning. *Research Quarterly for Exercise and Sport, 76,* 107–111.

Wulf, G., & Shea, C. H. (2004). Understanding the role of augmented feedback: The good, the bad, and the ugly. In A. M. Williams & N. J. Hodges (Eds.), *Skill acquisition in sport: Research, theory and practice* (pp. 121–144). London: Routledge.

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

Zimmerman, B. J., & Ponz, M. M. (1986). Development of a structured interview for assessing student use of self-regulated learning strategies. *American Educational Research Journal, 23,* 614–628.

Author's Note