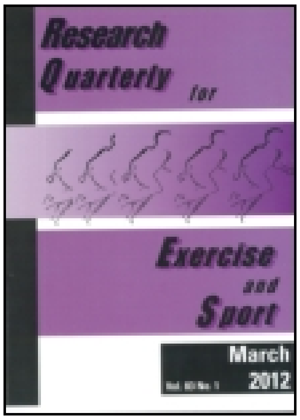

Research Quarterly for Exercise and Sport
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/urqe20

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Published online: 23 Jan 2008.

To cite this article: Suzete Chiviacowsky, Franklin Laroque de Medeiros, Angélica Kaefer, Raquel Wally & Gabriele Wulf (2008) Self-Controlled Feedback in 10-Year-Old Children, Research Quarterly for Exercise and Sport, 79:1, 122-127, DOI: 10.1080/02701367.2008.10599467

To link to this article: http://dx.doi.org/10.1080/02701367.2008.10599467

Research Quarterly for Exercise and Sport
©2008 by the American Alliance for Health,
Physical Education, Recreation and Dance
Vol. 79, No. 1, pp. 122–127

Self-Controlled Feedback in 10-Year-Old Children: Higher Feedback Frequencies Enhance Learning

Suzete Chiviacowsky, Gabriele Wulf, Franklin Laroque de Medeiros, Angélica Kaefer, and Raquel Wally

Key words: information processing, knowledge of results, motor learning, throwing

In the past few years, several studies have demonstrated the effectiveness of self-controlled practice for motor learning. These studies have examined how giving learners the opportunity to control a certain aspect of the practice conditions—such as the delivery of extrinsic feedback (e.g., Chen, Hendrick, & Lidor, 2002; Chiviacowsky & Wulf, 2002, 2005; Janelle, Kim, & Singer, 1995; Janelle, Barba, Frehlich, Tennant, & Caraugh, 1997), use of physical assistance devices (Wulf, Clauss, Shea, & Whitacre, 2001; Wulf & Toole, 1999), or demonstrations of the movement goal (Wulf, Raupach, & Pfeiffer, 2005)—affects learning. Typically, self-controlled practice conditions are compared to yoked conditions, in which each participant is yoked to one self-control participant. In the case of self-controlled feedback, for example, yoked learners received feedback on the same trials on which their self-control counterparts requested feedback. Allowing learners to control part of the practice conditions has been found to result in more effective learning, compared to predetermined (i.e., yoked) conditions. Possible reasons for those learning benefits include a more active involvement of the individual in the learning process and, in turn, deeper processing of task-relevant information (e.g., McCombs, 1989; Wulf et al., 2001) and enhanced motivation (e.g., Boekaerts, 1996; Chiviacowsky & Wulf, 2002, 2007).

The percentage of trials on which participants requested feedback in previous studies was relatively low: 7% in Janelle et al. (1995; underhand ball toss at target; feedback about movement form), 11% in Janelle et al. (1997; throwing with the nondominant arm at a target; feedback about movement form), 35% in Chiviacowsky and Wulf (2002; sequential timing task; feedback about segment movement times); an exception seems to a study by Chen et al. (2002; sequential timing task; feedback about overall movement time), in which participants requested feedback on 97% of the trials. While the frequency of feedback requests might depend on various factors, such as the nature of the task or on the exact instructions given to participants (e.g., the extent they encourage the learner to ask for feedback), there is a possibility that not all learners choose the "optimal" frequency of feedback, which, in turn, might have a qualifying effect on the learning advantages of self-controlled feedback. A recent study by Chiviacowsky, Godinho, and Tani (2005) did not support this view—at least for adult learners. The authors looked at the effects of different feedback frequencies chosen by adult participants. Specifically, Chiviacowsky et al. (2005) used a sequential timing task and compared two "extreme" groups of self-control participants, namely, those who chose the highest versus the lowest frequencies of feedback during practice. That is, of the 60 (self-control) learners in their study, they compared retention performances of the 20 participants who chose the highest frequencies (i.e., 50–99%) and

Submitted: September 1, 2006
Accepted: July 17, 2007

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those 20 participants who chose the lowest frequencies (i.e., 5–35%). The 20 participants "in the middle" were not considered in this analysis. The results showed no learning differences between the low-feedback and high-frequency groups, perhaps suggesting that adults have a relatively good feel for how much feedback they need to learn a task effectively.

In contrast to adults, children may not necessarily "know" how much feedback they need. While previous studies on self-control were conducted almost exclusively with adult participants, a recent study by Chiviacowsky, Wulf, Medeiros, and Kaefer (2006) demonstrated that the self-control benefits generalized to motor learning in 10-year-old children. The task required them to toss beanbags at a target. The results showed that accuracy scores in retention were higher for those who had control over feedback (on the accuracy of their throws), relative to yoked participants. In that study, the self-control group requested feedback on an average of 28.3% of the practice trials. In the present study, we asked whether differences in learning effectiveness would be found for children of the same age group (10 years) as a function of their self-selected feedback frequency. For example, would children who chose relatively low feedback frequencies show more effective learning than those who requested feedback more frequently? Such a finding would be in line with the guidance hypothesis (Salmoni, Schmidt, & Walter, 1984), according to which lower feedback frequencies are more beneficial to learning than high frequencies, as learners come to depend on the feedback if provided too frequently (e.g., Winstein & Schmidt, 1990; Wulf, Lee, & Schmidt, 1994; for reviews, see Schmidt, 1991; Swinnen, 1996; Wulf & Shea, 2004). Alternatively, it is conceivable that children who request feedback more often would actually show more effective learning than those who request less feedback. While there is a dearth of studies examining feedback frequency effects in children, there is some evidence that, in adults, learning relatively difficult tasks is not degraded by, and even seems to benefit from, high feedback frequencies (e.g., Swinnen, Lee, Verschueren, Serrien, & Bogaerds, 1997; Wulf, Shea, & Matschiner, 1998; see Wulf & Shea, 2004). Considering the relatively limited amount of experience most children have compared to adults, learning new motor skills might pose a greater challenge to them. Consequently, they may benefit from relatively frequent feedback. In addition, there might be other factors, such as limitations in children's attention span and their capability to process information relative to adults (e.g., Lambert & Bard, 2005; Thomas, 1980), which make it likely that children would benefit more from relatively high compared to low feedback frequencies. Therefore, it is conceivable children with higher self-selected frequencies would show more effective learning than those with relatively low frequencies.

An examination of this issue might shed more light on the effects of feedback frequency on children's learning and have implications for designing self-controlled practice conditions. For example, if greater learning advantages were found for children who requested feedback frequently, instructions could be given that encourage learners to ask for feedback. This way, it might be possible to further enhance the learning benefits of self-controlled feedback. The purpose of the present study was to examine whether learning in 10-year-old children—that is, the age group for which the Chiviacowsky et al. (2006) study found benefits of self-controlled knowledge of results (KR)—would differ depending on the frequency of feedback they chose. We surmised that a relatively high feedback frequency might be more advantageous than a low feedback frequency for children of that age group. We followed up on the Chiviacowsky et al. (2006) study, which used a beanbag tossing task, and used the methods of Chiviacowsky et al. (2005), which compared learning in participants who requested relatively high versus low feedback frequencies.

Method

Participants

Sixty 10-year-old children (28 girls, 32 boys; *M* age = 10.5 years, *SD* = 0.8), without physical or mental disabilities, participated in this study. They were recruited from a city center public school, located in southern Brazil. None of the participants had previous experience with the task, and all were naive as to the purpose of the experiment. Participants provided assent, and the school, as well as from the parents/guardians provided informed consent. They were also informed that the data gathered in the present study would be kept completely confidential. The university's Institutional Review Board approved this study.

Apparatus and Task

Similar to the study by Chiviacowsky et al. (2006), the task required participants to toss beanbags (100 g) overhand, with their nondominant arm, at a target placed on the floor. Hand dominance was determined by asking participants which hand they used to write. Participants stood behind a restraining line and tossed the beanbags at a circular target with a 10-cm radius, which was placed 3 m from the participant. Concentric circles with radii of 20, 30, 40, up to 100 cm were drawn around the target to assess the 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, 90, 80, 70, etc., 10 points were recorded, respectively, or 0 points if it landed outside the largest circle. In those cases, in which the beanbag landed on a line, the higher score was awarded.

Procedure

The practice phase consisted of 60 trials. Participants were prevented from viewing the target area by wearing opaque swimming goggles. However, they were allowed to look at the target while receiving instructions. Participants were informed that they would not receive feedback, or KR, about the accuracy of their throws unless they asked for it. The target area was divided into four quadrants, and KR was provided in terms of the direction and distance from the target center. Specifically, the experimenter informed the participant whether the toss was "long," "short," "left," or "right" (see Figure 1). In addition, the experimenter indicated whether the beanbag landed "near" (Zones 60–90) or "far" (Zones 0–50) from the target. If it landed in Zone 100, participants were informed the toss was correct (bull's eye). Approximately 24 hours after the practice phase, the retention phase was conducted. It consisted of 10 trials, during which participants were again prevented from seeing the target area while tossing. No KR was provided during retention.

Data Analysis

We created two groups of participants from the original 60. The "more-KR" group was composed of the 20 participants (10 girls, 10 boys; *M* age = 10.45 years, *SD* = 0.68) who requested the most feedback, while the "less-KR" group consisted of 20 participants (11 girls, 9 boys; *M* age = 10.45 years, *SD* = 1.05) who asked for the least. The average accuracy scores (points) for the practice phase were analyzed in a 2 (groups: more-KR vs. less-KR) x 6 (blocks of 10 trials) analysis of variance (ANOVA) with repeated measures on the last factor. Accuracy scores for the retention test were averaged across the 10 trials and analyzed in a one-way ANOVA. An alpha level of .05 was used for all statistical tests.

Results

Practice

Participants in the more-KR group requested KR on an average of 39.3% (range: 25.0–76.7%) of the practice trials, while those in the less-KR group asked for KR on 8.4% (range: 1.7–13.3%) of the trials. Figure 2 shows the accuracy scores of the two groups during practice. As can be seen, both groups increased the accuracy of their

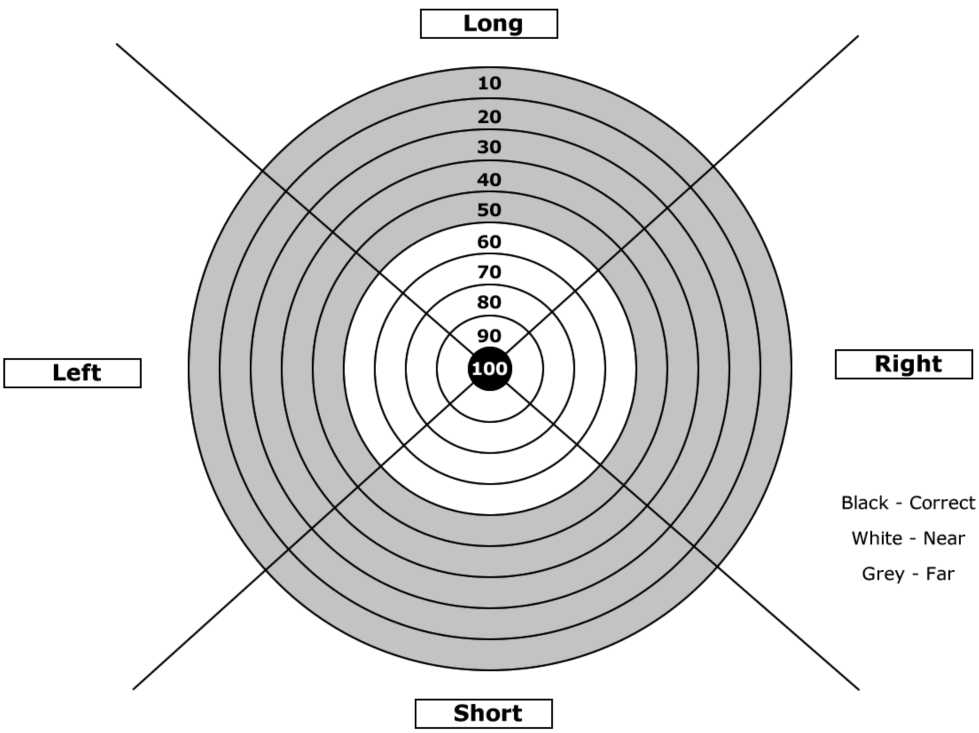

Figure 1. Schematic of the target area and zones used for providing feedback (e.g., "long, near").

tosses from the beginning to the end of the practice phase. The main effect of block was significant, $F(5, 190) = 9.04$, $p < .001$, whereas the group main effect, $F(1, 38) = 0.31$, $p > .05$, and the interaction of group and block, $F(5, 190) = 1.14$, $p > .05$, were not significant.

Retention

One day later, participants performed a retention test without KR. Compared to the end of practice, the less-KR group tended to show a drop in accuracy scores, while this was not the case for the more-KR group (see Figure 2). On the retention test, the more-KR group had higher accuracy scores than the less-KR group. The difference between groups was significant, with $F(1, 38) = 5.34$, $p = .02$.

Discussion

We sought to examine the effects of different self-selected feedback frequencies on motor learning in 10-year-old children. The average feedback frequency in the present study was 23.8%, which is slightly lower than the 28.3% found in the previous study by Chiviacowsky and colleagues (2006), who used the same task and children of approximately the same age. In that study, learners who had control over feedback delivery (self-control group) showed more effective learning than those who had the same feedback frequency and schedule but no control over it (yoked group). Thus, while self-controlled feedback can enhance learning in children relative to prescribed feedback schedules, the results of the present study suggest that the amount of this learning benefit may depend on the frequency with which feedback is requested. In the present study, which involved a considerably larger number of participants than the Chiviacowsky et al. (2006) study, participants who requested relatively little feedback (i.e., less-KR group: 8.4% KR) clearly showed less effective learning than those who asked for feedback more frequently (i.e., more-KR group: 39.3% KR).

There are several possible reasons for this. First, learning requires the development of an autonomous error-detection-and-correction mechanism, which, in turn, requires the performer to compare her or his intrinsic feedback with the extrinsic information, such as KR. This way, a "meaning" is attached to the intrinsic feedback, and it becomes interpretable in the future. Through this constant tuning process, the error-detection-and-correction mechanism is developed and refined with experience. Because of children's relatively limited experience, the tuning process would be expected to be facilitated by relatively frequent feedback independent of whether or not it is provided on demand.

Furthermore, children generally differ from adults in their capability to process information (Badan, Hauert, & Mounoud, 2000; Chi, 1977; Connolly, 1970, 1977; Fayet, Minet, & Schepens, 1993; Lambert & Bard, 2005; Thomas, 1980). Developmental changes in memory capacity (i.e., retaining and organizing information) and the ability to use strategies (i.e., manipulating information in short-term memory) affect processing speed, which increases from 3 years of age to adolescence (Badan et al., 2000; Chi, 1977; Lambert & Bard, 2005). That is, with increasing age, the same informational load can be processed in less time, thereby enhancing the individual's ability to use information effectively and efficiently. Specifically, 10-year-olds and adults differ in their information-processing rate (i.e., bits/s) in various tasks, such as two-dimensional pointing (Lambert & Bard, 2005) or sequential pointing (Badan et al., 2000). The limitations in information processing in children can also affect the motor learning process (Thomas, 1980) and specifically the use of feedback (KR). The ability to use KR to improve performance increases with age (Barclay & Newell, 1980; Newell & Kennedy, 1978). Barclay and Newell (1980), for example, used self-paced post-KR intervals and found that 10–11-year-olds either did not use those intervals efficiently to improve their performance (Experiment 1), or took more time to process the KR (Experiment 2). Thus, a greater exposure to KR (i.e., a higher frequency) might make up for those processing limitations, resulting in more effective learning than occurs at a lower KR frequency.

Finally, there is evidence the learner benefits from frequent feedback, compared to reduced feedback (e.g., Swinnen et al., 1997; Wulf et al., 1998; see Wulf & Shea, 2004, for a review) when learning relatively difficult and demanding tasks. That is, the negative effects associated with the guidance provided by frequent feedback seem

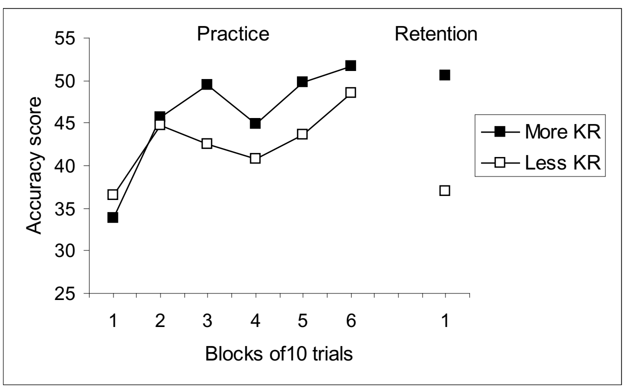

Figure 2. Accuracy scores during practice and retention of the groups that requested more ($M = 39.3\%$ of trials) and less ($M = 8.4\%$ of trials) feedback during practice.

to be reduced. The same might be true for relatively inexperienced or young learners for whom tasks that may be "easy" for adults are relatively difficult.

The results of the present study suggest the amount of feedback participants select may qualify the learning benefits of self-controlled feedback. Assuming there is an optimal range for the amount of feedback necessary to learn a certain task—which presumably depends on learner characteristics, such as level of experience or age—not all individuals would be expected to request feedback within that range. To further enhance the learning process, instructions could be devised that encourage participants (e.g., children or inexperienced learners) to ask for feedback frequently, or discourage them (e.g., adults or experienced learners) from doing so. The present results suggest that some children may have a tendency to request feedback, if given the opportunity to do so, at a lower than optimal rate. Future studies should examine whether supplemental instructions could be used to enhance the effectiveness of self-controlled feedback. Alternatively, the feedback frequency could be predetermined, for example, by letting the learner decide on which three trials in each six-trial block he or she wants to receive feedback (see Chiviacowsky & Wulf, 2005). While this would limit the learner's degree of self-control, the benefit of a more appropriate feedback frequency for all learners might outweigh that potential disadvantage. Clearly, future studies are necessary to examine these issues in more detail.

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Authors' Note

The study was supported by scholarships from the from Research Support Foundation of the State of Rio Grande do Sul, Brazil (Angélica Kaefer), and from the National Council of Scientific and Technological Development, Brazil (Franklin Medeiros and Raquel Wally). Please address all correspondence concerning this article to Suzete Chiviacowsky, Escola Superior de Educação Física, Universidade Federal de Pelotas, Rua Luís de Camões, 625 - CEP 96055-630, Pelotas - RS – Brazil.

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