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Effect of error detection and time of decision making for request feedback in self-controlled conditions acquisition and retention of a complex task

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ABSTRACT

The present research examined the Effect of error detection and time of decision making for request feedback in self-controlled conditions acquisition and retention of Breaststroke. For this purpose, seventy five students studying at Lahijan University were randomly divided into five groups: teacher-controlled (TC), self-controlled before (SCB), self-controlled before with error detection (SCB+ED), self-controlled after (SCA) and self-controlled after with error detection (SCA+ED). The learners participated in the pre-test, acquisition phase and retention test. Acquisition phase consisted of two sessions with 10 blocks of six trials; this was done separately for each segment involving the Arm stroke, Leg kick and Coordination portions. For each segment of the retention test, learners participated in the test 48 hours after the second training session. Data were analyzed by repeated measures and a 2 × 2 (time of decision making and error detection) ANOVA. Findings showed that the SCA and SCA+ED groups performed better than the other groups. Furthermore, all of the self-controlled groups, except for SCB, exhibited better performance than the TC group on the retention test. It can be concluded that the deciding time for feedback with the estimated error before receiving the demanded feedback resulted in better learning and retention.

Keywords: Self controlled, error detection, retention, learning, decision making

INTRODUCTION

Over the years, researchers have examined the role of augmented feedback on learning [16, 20, 21]. Previous studies showed that self-controlled learning has beneficial effects on learning processes. Therefore, there is little disagreement that learner-control practice is one of the most important variables for motor learning [2]. Researchers have recently begun to examine the effects of self-control feedback on motor learning [12, 27]. It has been demonstrated that self-controlled learning has a big impact on the effectiveness of practice [27]. The first investigation about the effectiveness of giving self-controlled feedback for motor learning was Titzer's study [26]. Another initiator study determined that one way to enhance the effectiveness of feedback is by permitting learners to decide when they want to receive feedback compared with the yoked group (in the yoked group, each learner receives the same feedback schedule as a member of the self-controlled group. Therefore, the amount and the schedule of feedback received are same for both groups; the only difference is that one group decides the order and amount of feedback individually) [13]. Other research studies found more advantages from learner-controlled feedback during learning a timing task [27]. Furthermore, a study demonstrated that allowing participants to choose when they can use physical assistance devices in the ski-simulator task produced responses that were similar to the yoked condition [7].

Another topic related to self-controlled feedback is the amount of feedback and the reduction of feedback frequency. It has been suggested that KR (knowledge of results feedback) is used for motor learning in two ways: (a) a learner needs KR to test a hypothesis about the correctness of the previous response, and (b) each tested "response hypothesis" contributes to a better memory of that response [16, 23]. Therefore, after finishing a trial, the learner will estimate how much success has been achieved. Then, the learner will assess the amount of correctness of the estimation by comparing with the received KR. From this comparison, a response hypothesis was derived for the succeeding response [10]. Previous researchers have demonstrated that when participants were required to estimate response errors during acquisition performance, they produced better retention performance than participants who did not estimate the errors [1, 24].

The consensus is that a small amount of feedback about KR is necessary for learning of a new skill [10, 19] that would guide the upcoming responses. However, if participants receive a high KR frequency during acquisition, they fail to use additional memory processes that is important for learning; this is referred to the "guidance hypothesis" [18, 21]. In contrast, when participants were provided with a lower KR frequency, it encouraged them to become involved in additional learning processes (e.g., they were able to detect the errors and amend them in the absence of feedback) and this, in turn, promoted memory development [10]. To investigate this prediction, researchers used different plans for giving KR with variable frequencies. For example, they reduced or delayed the KR frequency with average feedback [28] or summary feedback [18]; some of them showed that a reduction in frequency resulted in better performance [10]. Adams noted that when the KR presentation was postponed, the learner was able to strengthen only that which was learned from the previous responses with KR [1].

In self-controlled practice, the learner receives a reduced or delayed feedback that is more effective for the learning process. Regarding the benefits of self-controlled feedback, one reason for this phenomenon is the function of self control as a portion of self regulation that has been previously discussed in the verbal and cognitive learning domains [4, 17, and 29]. It has been assumed that this self regulation promotes deeper processing of relevant information because it augments the ability to detect and correct errors [5]. Also, it has been suggested that giving learners the control of practice regimen might increase their motivation [2], thereby promoting the use of self-regulation strategies and encouraging the learners to take charge of the learning process [9, 14]. Other investigations suggested that self-controlled feedback encourages learners to explore different movement strategies and it may be more tailored to the learner’s needs, relative to yoked conditions [6, 27]. Recently, researchers have become interested in investigating the effects of self-controlled feedback demonstrations with requesting before or after the trial. However, if an advantage of self-controlled feedback is that learners receive feedback when they want, and if this preference is a function of their performance in a given trial, the learning benefits should be greater if learners can make a decision after, rather than before the trial. When learners have to decide before the trail, they do not know what the outcome will be or whether they will need feedback. As mentioned before, learners with error detection after the trial perform better in retention trials than learners who do not estimate their errors [24]. One explanation is that error detection requires participants to create a “response hypothesis” about the previous response and encourages them to use additional memory processes [19]. This permits them to use the KR to test the response hypothesis [10]. Furthermore, the “stability hypothesis” recommended by Lai et al. (2000) proposed that conditions that promote inter-trial response stability will enhance the learning [15]. Also it is noted that this enhancement may be caused by various manipulations like self-controlled feedback and/or request-detecting errors and can subsequently be corrected [3].

According to the above arguments and as recommended in Chiviacowsky & Wulf’s research [7], the main purpose of this study was to determine whether the effects of time of decision making in self-controlled feedback (demanding feedback before or after performing a trial) was congruent with error detection (with or without error reporting) in learning a complex task.

MATERIALS AND METHODS

Participants:
Seventy five undergraduate students (age: 21 ± 2.2 years old) participated in the experiment. Informed consent was obtained from all participants. None of them had been tried the breaststroke, and anyone could float for at least 1 minute on the water's surface.

Apparatus and task:
Two video cameras (Model: Sony HVR-V1P, Japan) were used; one moved on a railway and recorded the movement from the next, to the learner and the other was fixed in front of the learner (0.2 meters above the water's surface) at the edge of the pool. Three professional swimming coaches who had taught swimming course in the kinesiology department were recruited to prepare a checklist of the details of the breaststroke and score them. Afterward, eight persons recruited for a pilot study to preview the reliability of the scoring procedure and the checklist (using the interclass correlation coefficient). Then we divided the breaststroke into three main segments (Hand (Armstroke), Leg (Leg kick) and Coordination). At first, learners participated in the pre-test before starting the actual trial. Afterward, in the training phase (acquisition), participants trained for 2 sessions with 10 blocks each in 6 trials; this was done separately for each segment involving the Hand (Armstroke), Leg (Leg kick) and Coordination portions (second training session was held 24 hours after the first training session). They held a kick-board between their hips during the Hand movement, and caught it between their palms during the Leg movement. The rest time was 90 seconds between blocks. At first, we asked learners to read the scaling table 10 minutes before we started teaching the related movement. Then, an international swimming coach showed participants the skill for the related segment (2 blocks × 6 trials) and another coach described the main details simultaneously. Afterward, all of the acquisition tests were given based on the instructions immediately after the last trial of every training session. To learn the Hand and Leg movements, the trainers were told to focus on the Propulsion and Recovery Phases. For the Coordination segment, the trainers focused on Propulsion (fluency of movement), Efficiency of Arm-Leg pressure and relative timing. For the Hand (Armstroke) and Coordination segments, the highest score was 12 and the lowest was zero. For the Leg segment (Leg kick), the highest score was 24 and the lowest was zero. Based on the coaches scaling, the importance of three segments were scored equally. Because the details of the Hand and Coordination segments consisted of three scaled items and the values were similar to the Leg segment, the scores multiplied by two (× 2) to prevent errors in evaluation of the Hand and Coordination segments. Therefore, the highest score for the Hand and Coordination was 24 (12 × 2) and the lowest was zero. For each segment of the retention test, learners participated in the test 48 hours after the second training session. The test involved 2 blocks × 6 trials. All of the trials and tests were recorded by video camera, and evaluated and scored by the three swimming coaches already mentioned (every trial during the training and retention tests included one movement for each particular segment).

Procedure:
Participants were randomly divided into five groups; the teacher-controlled (TC) group received 30% feedback in an interval manner, as used in the Chiviacowsky & Wulf study [7]. Also, some researchers reported that the best performance in retention tests was 33% frequency of feedback [9]. The other four groups were self-controlled before (SCB), self-controlled before with error detection (SCB-ED), self-controlled after (SCA), and self-controlled after with error detection (SCA-ED). Participants in all self-controlled groups were informed that they were able to control when they received feedback. The only limitation was that they had to request feedback on 3 of 10 trials. They were also informed that they eventually would have to do the tasks without receiving feedback. In the SCB group, participants decided to receive feedback about that performance before starting it. However, in the SCA group, they decided to receive feedback after finishing the trial, as in previous studies [7, 12]. Both error detection (+ED) groups were asked to estimate scores of those performances before receiving any augmented feedback by watching one round of those movements in slow motion that was recorded from the last 6 trials; this was done after 10 seconds of finishing that block, forcing them to score those performances within 60 seconds (after this estimation, the teacher was giving them the feedback in 30 seconds remaining). This error estimation was requested only during blocks where the learner asked for feedback.

To score the segments, we used rating scales with 5 scores (0 to 4) as mentioned in Thomas et al [1]. This scoring was based on the segment that was being taught. The final score that was used for the assessment was the average of the trials recorded by three observers (coaches) with help of the videotape in each evaluation block (pre-test, at the end of day 1 and also day 2 of training and in the delayed-retention test). To assess the validity and reliability of the procedure, the experiment was first done with eight subjects who were divided into the same experimental groups, and the results were evaluated as part of a pilot study using the interclass correlation coefficient (r = 0.88).

Statistical analysis

To assess the level of performance in the acquisition phase in 5 (groups) × 2 training sessions, we used an analyses of variance with repeated measures and a 2 × 2 (time of decision making and error detection) ANOVA for all retention tests. Also descriptive analyses (mean ± SEM) were used to determine the average of performances. To quantify the results, we used the mean of scores recorded by three observers from two videos recorded at different places**.**

RESULTS

Acquisition:

Average scores recorded in trainings were used to assess performance improvement. As described before, we analyzed the results of three segments (Hand, Foot and Coordination).

The Hand segment:

As shown in Figure 1, there was an improvement in the scores produced by the groups as the training progressed. In the first session, the differences between average scales of the SCA-ED, SCA and SCB-ED groups were not significant. Whereas performances of the SCB and TC groups were weaker at the end of the acquisition period. In the second session, it was a significant difference between the SCA-ED and other groups, F (4, 70) = 119.2, $p < 0.05$. Performance of the SCB and TC groups was the same, whereas there were significant differences between these two groups with the three others; F (4, 70) = 47.9, $p < 0.05$ and F (4, 70) = 20.58, $p < 0.05$ respectively).

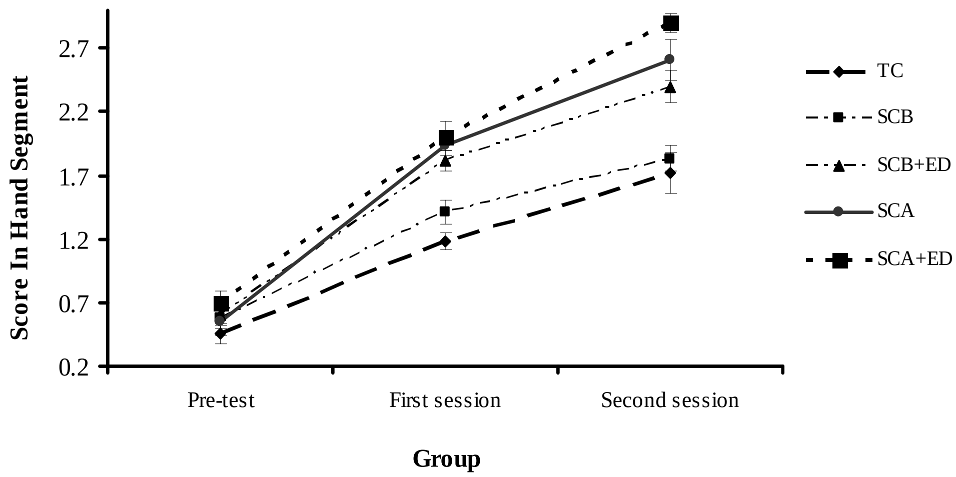

Figure 1. Effects of different feedback on Hand performance during the training period.

The Leg Segment:

As shown in Figure 2, the best performance at the first session was demonstrated by the SCA-ED group. There was no significant difference between the TC and SCB groups. Also, at the end of acquisition, SCA-ED members performed best, F (4, 70) = 40.90, $p < 0.05$ and the worst scores were produced by the TC and SCB groups.

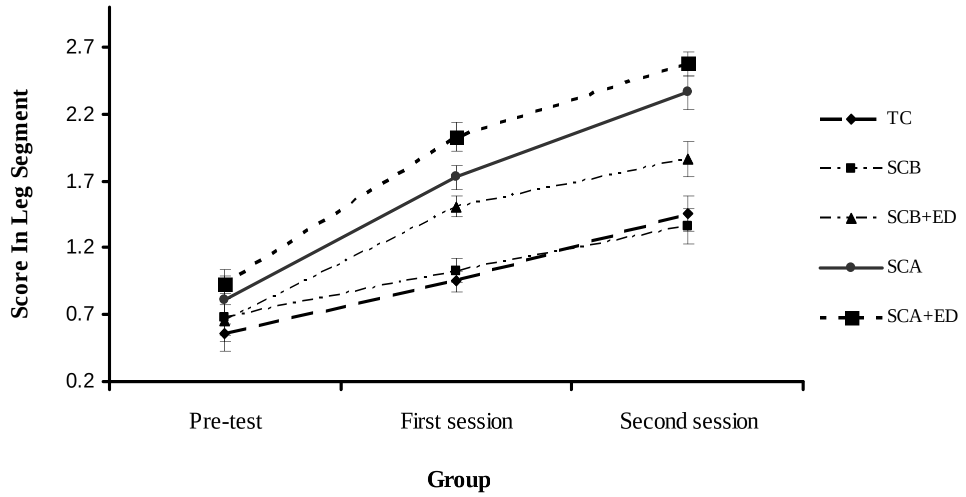

Figure 2. Effects of different feedback on Foot performance during the training period.

The Coordination Segment:
As shown in Figure 3, there was a significant difference between the SCA and SCA-ED groups with the three other groups [F (4, 70) = 29.8, $p < 0.05$ and F (4, 70) = 38.14, $p < 0.05$, respectively] in the first session. In the second session, the SCA-ED group had the best scores, and it was significantly different from the other groups. In all segments, there was a clear increase in the scores during both the training and trial sessions, but this increase had the different levels.

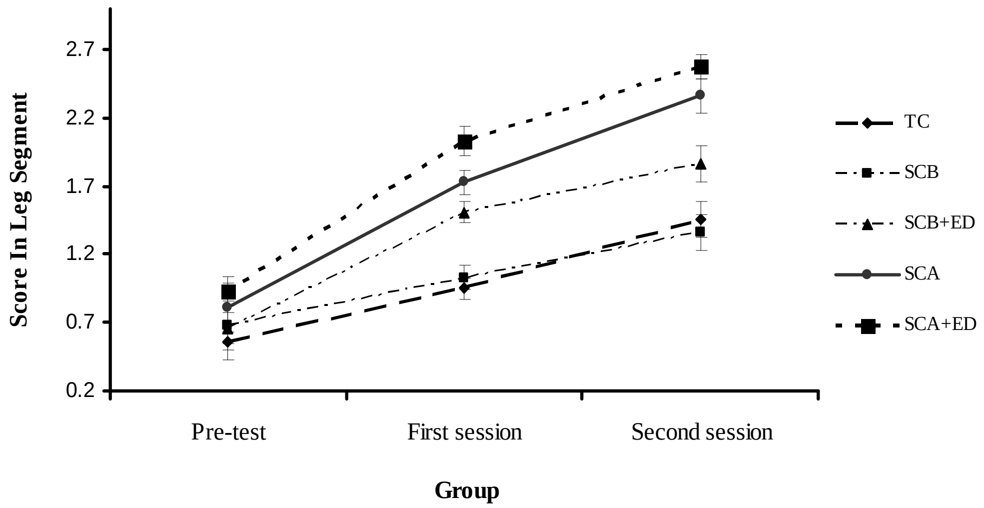

Figure 3. Effects of different feedback on Coordination performance during the training period.

Total acquisition (average of three segments):
In each segment, there were differences between the pre-test, and both the first and second sessions in each group (Figure 4). In the TC group, there was a significant difference [F (4, 70) = 20.71, $p < 0.05$] between the pre-test from the first and second sessions, where $p < 0.05$. In the SCB group, there was significant difference, F (4, 70) = 12.25, $p < 0.05$, between the pre-test from the first and second sessions, $p < 0.05$, and also between the first session and second session, where $p < 0.05$. In SCB-ED, significant differences were found [F (4, 70) = 58.19] between pre-test from the first and second sessions, where $p < 0.05$. Finally, in the SCA and SCA-ED groups, there were significant differences [F (4, 70) = 73.71, $p < 0.05$ & F (4, 70) = 129.57, $p < 0.05$] between the pre-test and both first and second sessions and also between the first session and the second session, $p < 0.05$.

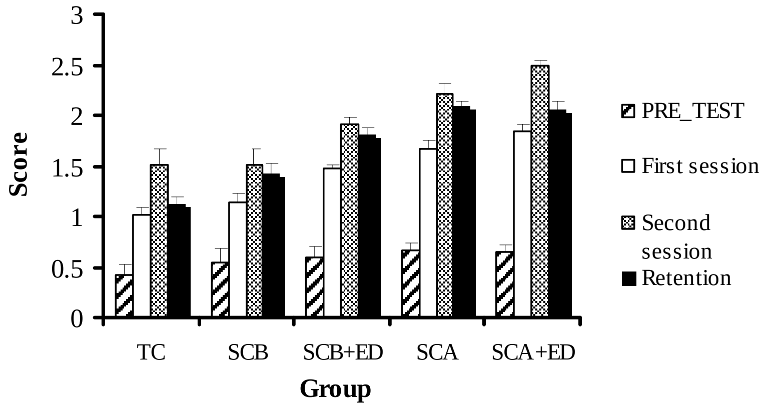

Figure 4. Differences between total (average of three segments) scores during the acquisition and retention periods.

In the pre-test, as shown in Figure 5, there were no significant differences between the groups. During the first session, there were significant differences, F (4, 70) = 23.05, $p < 0.05$, between the TC and all the SCB-ED ($p < 0.05$), SCA, ($p < 0.05$), and SCA-ED ($p < 0.05$) groups. The SCB score was significantly different from SCB-ED ($p < 0.05$), SCA ($p < 0.05$) and SCA-ED ($p < 0.05$) groups. The SCB-ED score was also different from the SCA-ED score ($p < 0.05$). During the second session (Figure 5), there were significant differences [F (4, 70) = 14.41, $p < 0.05$] between TC and all the SCB-ED, SCA and SCA-ED groups, where $p < 0.05$ for all groups. Also significant differences were shown between SCB-ED with SCA and SCA-ED, $p < 0.05$ for all. All groups demonstrated an increase in overall scores as the training period progressed. As shown in Figures. 1-3, performances by the SCA groups were better than others. Also, the SCB-ED score was not significantly different from either SCA or SCA-ED group.

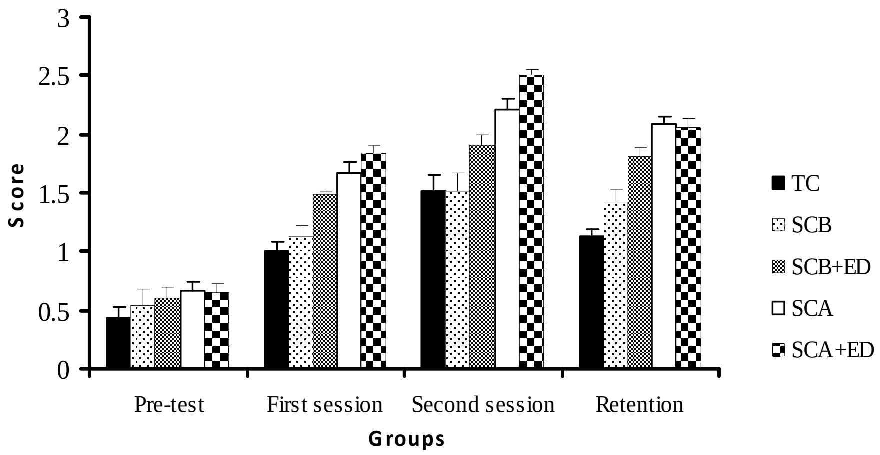

Figure 5. Differences between total (average of three segments) scores during the acquisition and retention periods of every test.

Retention:

The retention test was done 2 days after the training period. As shown in Figure 4, in the TC group there was a significant difference between the pre-test and retention test ($p < 0.05$). In the SCB group, there were significant differences between the retention test and the pre-test same as the first session result, where $p < 0.05$ for both. Also, significant differences were found between the retention test and the pre-test, ($p < 0.05$) in the SCB-ED group. In the SCA group, there was a significant difference between the retention test and both the pre-test, and the second session results, $p < 0.05$. In the SCA-ED group, the significant difference was seen between the retention test and both the pre-test, and the second session results ($p < 0.05$).

Comparison between retention tests:
Significant differences were found (Figure 5) in the retention tests between the groups [$F(4, 70) = 28.78$, $p < 0.05$]. There were significant differences in scores between the TC and all the SCB-ED, SCA and SCA-ED, SCB-ED and SCA-ED groups, and also between SCB and TC groups ($p < 0.05$ for all). The SCA had higher scores than the SCB group; although, the SCB-ED group was not significantly different from the SCA-ED group.

DISCUSSION AND CONCLUSION

All self-controlled groups, except for the SCB group, performed better than the TC group. Giving learners different control of the practice regimen (e.g. self-controlled feedback or error detection) might increase their motivation [2]. This may promote the use of self-regulation strategies [14] and encourage participants to take charge of learning process [5] or explore different movement strategies [27].

According to the acquisition period, the best performance was observed in the second session rather than in the first session or the pre-test. This confirms "the progression of training" [9] and supports the “guidance hypothesis”, which describes the important role of feedback for guiding the performer to the correct movement [6]. Also, this increase in performance confirms the “stability hypothesis” proposed that inter-trial response stability should increase learning [17]. Another suggestion is that the significant difference between the SCA, SCB, and TC groups might be the result of using error detection intrinsically, whereas learners in the SCB group were prevented using their error estimation before getting feedback [19, 23]. The other notion is that the subjects in the SCB group might pay more attention to the performance because they decided to receive feedback before the trial. However, this difference was not significant between the SCB-ED group and the two SCA groups (SCA and SCA-ED). This finding was similar to that obtained by Chiviacowsky & Wulf [23]. It seems that learners in the SCB-ED group used automatic intrinsic feedback. When learners expressed these self-recognizing errors, they were forced to compare the errors with given feedback to test the correctness of error detection [16, 21]. Recent views of motor learning have indicated that measures of performance during training are not generally good predictors of long-term learning, whereas there are usually best evaluated with retention and/or transfer tests [3]. Therefore, we used the delayed-retention test and showed that all self-controlled conditions, except for the SCB group, caused better learning than the teacher-controlled situation (TC). This finding was similar to those of Chiviacowsky & Wulf's study [23] who found no significant difference between the two groups during practice and retention, but the transfer test indicated clear learning differences. Therefore, self-controlled conditions may be more tailored to the learner's demands relative to yoked conditions. Also, it is possible that such manipulation could affect cognitive learning domains [14, 26] or promote deeper processing of relevant information [13]. In particular, self control seems to enhance the learner's motivation, resulting in deeper information processing and improving retention [2]. Furthermore, the difference between the SCB-ED, SCA and SCA-ED groups and the TC was significant. Therefore, the learning process produced more progression in these groups. Apparently, this difference was the result of the extra manipulations that mirrored the self-controlled feedback, request to estimate errors and subsequent correction of these errors mentioned in Bruechert's study [12]. Also, the difference between the SCB and SCB-ED groups could be due to error detection after the trial. This finding supports the findings reported in a study by Swinnen et al. [24]. One explanation is that the error estimation may enable learners to produce better retention than learners who do not estimate the errors. The other finding is that error estimation requests participants to create a "response hypothesis" [3, 16] about the previous response, and this encourages them to use additional memory processes [4] that permits them to use the KR to test these response hypotheses [10]. Finally, it is plausible that error estimation encourages learners to attend to their intrinsic feedback and compare that with extrinsic feedback. In this study, we also showed that the increase in both the relative timing details and movement components were the same as the movement width and efficient pressure to water. Thus, manipulating the time of decision making (giving feedback after the trial) and also estimating the error have certainly affected the generalized motor program (relative timing details). This finding is in agreement with Chiviacowsky & Wulf's study [23], but is in contrast to those another study [8], who found no difference between SCB and SCA groups with respect to relative timing tasks. The assumption is that the disagreements between the tasks (complex versus simple) used by Chiviacowsky & Wulf's study [8] maybe the reason. Another assumption is that the restriction of the amount of feedback (30%) may cause the differences. In this parameterized learning study (width and pressure), our findings were consistent with Chiviacowsky & Wulf's study [8]. It differed from Chiviacowsky & Wulf (2005), who found no advantages using self-after for absolute timing; they used absolute timing tasks to assess the learning of parameters. It may be due to the use of complex skills in our study compared to the simple task that they used. It can be very beneficial to compare simple and complex tasks in the same situation as it allows the assessment of the effectiveness of decision-making interactions by error detection.

Also, as argued by Chiviacowsky & Wulf's study [23], self-controlled learners are free to decide how often and when to receive feedback. In this study, however, the learners were required to give 30% feedback (before or after). This suggests that using self control without any restriction may help to understand various aspects of this field.

In general, our findings showed the advantages of SCA in the learning process. Also, it revealed that error detection in SCB had the same effects as SCB feedback on both acquisition and retention tests. In conclusion, SCA—with or without error detection feedback— influenced complex movement skills.

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