The effects of average KR schedule and decided movement rhythm on learning of timing

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《ABSTRACT》

The purpose of the study was to examine the effects of average feedback length and decided movement rhythm on the acquisition and retention of timing movement patterns. In this study, the task consisted of five movement components (submovements): (1) press a starting button, (2) knock down first barrier, (3) knock down second barrier, (4) knock third barrier, and (5) press a stop (goal) button. The goal movement time for the subjects to complete the five submovements was 1200 ms. The subjects were requested to finish the five submovements either with a 300-ms fixed interval (decided task), or a self-determined interval (free task), between any two submovements. The subjects were provided either 100% KR, or 3-trial average KR, or 5-trial average KR, depending on the conditions. The results indicate that the decided movement rhythm led to a delay in the acquisition of timing movement patterns. The author claims that the average of three trials associated with KR after every trial tended to be an appropriate length for the acquisition of timing movement patterns; however, there is little support from the data.

Keywords: average KR, rhythm, timing movement pattern

I. Purpose

In acquiring motor skills, knowledge of results (KR) is terminal feedback provided to the performer after the completion of a response about the movement outcome in terms of an environmental goal (Adams, 1968, 1971), such as the overall movement time or spatial deviation from a target. This information is very important for error detection after a response and to serve as a basis for error correction on subsequent trials. In this context, a learner's performance stabilizes and becomes more accurate through physical practice. However, it has been indicated that, if the learner received too much KR, their performance might not be maintained during retention trials. One reason for this is that too high a frequency of KR may lead to a learner becoming dependent upon that information (Schmidt, 1991a), and may lead to overcompensation such that a learner will try to correct the errors from the inherent noise process in the neuromuscular system, labeled as "maladaptive short-term correction" (Schmidt, 1991b). Another reason for this is that, in the absence of KR, a learner should utilize self-error detection and correction using inner feedback information when practicing. However, it becomes disadvantageous to the retention of performance if dependency upon KR increases, labeled as "the dependency-producing effects of feedback" (Schmidt, 1991a).

Summary and average KR is one method of avoiding the phenomenon of the dependency-producing effects of feedback (e.g., Schmidt, Young, Swinnen, & Shapiro, 1989; Schmidt, Lange, & Young, 1990; Schmidt, 1991a; Yao, Fischman, & Wang, 1994; Guadagnoli, Dornier, & Tandy, 1996). Generally speaking, with this method, performers are provided with KR about a set of trials after this set has been completed. Yet, whereas summary KR involves providing KR about every trial in the set, average KR refers to the average performance on a set of trials. Yao, *et al.* (1994) considered the effectiveness of summary feedback and average feedback methods using a movement timing task which required participants to move a stylus 40 cm in 500 msec. The effect of different summary lengths and average lengths of trial were also examined. A summary length and average length of five trials was found to be most effective with respect to the retention test. When KR was given after each trial, the learner was given information regarding the accuracy of performance as external feedback. As a consequence, the learner was dependent on external feedback and needed the information to correct their timing. The learner who was given KR after each trial was less reliant on self-error correction, and this had a detrimental effect on retention of performance. Conversely, in a summary or average feedback schedule, since there is less external feedback information, a learner seemed to pay more attention to internal feedback such as muscle sensitivity and timing. As a result, Yao, *et al.* (1994) concluded that a learner becomes more sensitive to their own reaction-reproduction feedback in a summary or average feedback schedule, and this is advantageous to retention of performance. Butki & Hoffman (2003) considered the effective summary length of average KR using a golf putting task. Results showed that the continuous KR group, who received continuous KR about ball path and final location, performed better during acquisition, but the KR-deprived groups, who were deprived of specific KR on 50% or 100% of the acquisition trials, performed better on delayed retention trials. The results of Yao, *et al.* (1994) and Butki and Hoffman (2003) indicated that the learner becomes dependent on augmented KR and is unable to use intrinsic feedback, and that the optimal summary length appears to depend on the complexity of the task.

Ishikura (2005) used a barrier knock-down task to examine the influence of length for average KR and task complexity. In addition, they examined the effects of average knowledge of results on the learning of movement parameters. In his study, the number of barriers which were pushed down defined the complexity of the movement. The case where one barrier was pushed down was set as a simple task, and the case where three barriers were pushed down was set as a complex task. The results of analysis indicated that, given KR after every trial and given average KR of three trials, perticipants' performance was more accurate and more stable than when they were given average KR of five trials. Note that these results had high task specificity. According to Henry's specificity hypothesis (Henry, 1968), it suggested that the number of motor abilities specific to a particular task is very large, and that the correlation between the abilities to be learned among similar tasks is nearly zero or at least very low. The movement timing task used by Yao, *et al.* (1994) and Schmidt, *et al.* (1989), and the golf putting task used by Butki & Hoffman (2003) seem to have the similar task specificity, and internal feedback may be focused on less than in a barrier knock-down task. Considering these studies, it may be that the advantageous effects of the average KR method depend on task specificity.

The present study took into account task difficulty and examined its relationship with the summary length for average KR. In addition, effects of average KR on the learning of movement parameters were examined. In this study, a barrier knock-down task was used (see Fig. 1 below). The difficulty of the movement was defined in term of the decided movement

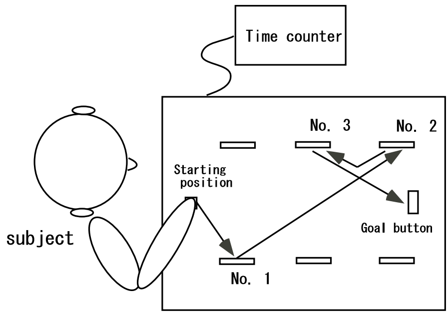

Figure 1. The barrier knock down task: the free task required a participant to knock down three barriers and press the goal button 1200 msec after pressing the start button. The decided task required the participant to knock down three barriers at 300 msec intervals.

rhythm required by a participant to knock down three barriers at 300 msec intervals. The case where three barriers were pushed down with participant's own rhythm was set as a free rhythm, and the case where three barriers were pushed down with decided time was set as a decided rhythm. If the phenomenon of the dependency-producing effects of feedback was examined by learning of timing, it would be expected that the influence of average KR length and task difficulty would appear as a learning effect. That is, as a result of comparing the decided rhythm with the free rhythm, it was expected that the error in the movement would be larger, and that the learning effect of a parameter would not be predictable. On the other hand, it was expected that the summary length most advantageous to learning with the free rhythm would be longer than for the decided rhythm. Moreover, if it could be assumed that a learner's own reaction-correction feedback process is activated during skill acquisition, a learner's capability for error detection and correction would be increased (Schmidt & White, 1972; Newell, 1976; Newell & Shapiro, 1976; McCracken & Stelmach, 1977).

It was expected that the estimated movement time for performance after a trial would coincide with movement time, and that the difference between the estimated time (trial n) of performance after trial and the target time would coincide with the difference between the next performance time (trial n+1) and performance time (trial n) (Blandin & Proteau, 2000).

II. Method

Subjects We asked the participants before an experiment started which hand they would use. Individuals self-reporting right-handedness were scheduled as participants. The subjects who participated in this experiment were 72 university students (36 men, 36 women; M = 20.00, *SD* = 1.56). The subjects had no experience with learning this experimental task before.

A task and apparatus The apparatus (made by the Shin-Osaka company) is illustrated in Figure 1. It consisted of six wooden barriers (10 cm x 8 cm), a start button, and a goal button. The start button, the goal button, and the six wooden barriers were connected to a digital timer. Microswitches were set in the bottom of the six wooden barriers, and the mechanism was such that the time counter stopped as soon as a wooden barrier inclined. The goal button was located 46 cm opposite the start button. Three wooden barriers had been arranged on both sides of the axis between the start button and the goal button, which were 40 cm apart. The three barriers on each side were set at intervals of 10 cm, respectively.

The subject was requested for the timing task, to push a goal button exactly 1200 msec after pushing a start button. Furthermore, after pushing the start button, a subject was required to knock down three barriers before pushing the goal button (from No. 1 barrier to No. 3 barrier in Fig 1).

Procedures and experimental groups The subjects were divided into six groups by two tasks (free task / divided task) x three experimental groups

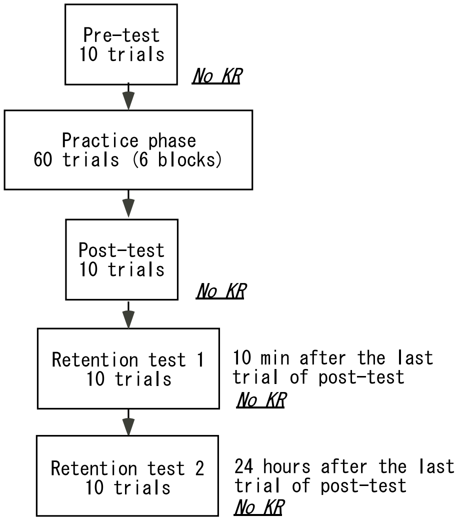

Figure 2. Experimental procedure.

(100% KR / Avg 3 / Avg 5). Each group numbered 12 people (6 men and 6 women). Each subject participated in five experimental phases (see Fig 2). The subjects of the 100% KR group were informed of the time it took them to push the goal button after pushing the start button immediately after each trial as feedback information. The average time for 3 trials was given to the subjects of the Average 3 group as feedback information every third trial. In the Average 5 groups, the average time of 5 trials was given to the subject every fifth trial. In addition, the subjects in the decided task were asked to push down three barriers, one every 300 msec. On the other hand, the subjects in the free task were required to push down three barriers with their own free time interval.

After explaining the procedure and task of the experiment to each subject, all the subjects took a pre-test of 10 trials which did not affect the KR score. Each subject was requested to estimate the time spent on performance at this time. Next, the physical practice phase of 60 trials was taken. At this time, one type of KR was explained to the subject orally. Therefore, in the physical practice phase, KR was given 60 times to the 100% KR group, and the 20 times to the subjects of the Average 3 group, and 12 times to the subjects of the Average 5 group. KR was shown in whole msec. The immediate test was started immediately after the 60th trial of a physical practice phase. Retention test 1 was taken 10 minutes after the immediate test was finished. Then, retention test 2 was taken 24 hours after that. The transfer test was taken after the immediate test and the retention tests 1 and 2. In the transfer test, although the barriers were pushed down in the same movement patterns as the previous tasks, the subjects were requested to push the goal button only 1000 msec after pushing the start button. An immediate transfer test, the retention transfer test 1 and 2, and the retention tests 1 and 2 followed the same schedule as the pre-test (performance and time estimate of 10 trials without KR), respectively.

Dependent variables The data for 60 trials in the physical practice phase was summarized into blocks of ten trials. In order to evaluate the performance result of each test, the absolute constant error (|CE|) and the variable error (VE) were chosen as dependent variables. To consider the mechanism of error detection, the correlation was calculated between the Movement Time and the Estimated Movement Time on trial n. Positive high correlation suggested that a subject's Estimated Movement Time was correct. The estimation error, the difference between the Estimated Movement Time and the target Movement Time (i.e., 1200 msec) was calculated on trial n. The actual correction is the difference of Movement Time on trial n+1 and Movement Time on trial n. This measure indicates the size and the direction of the correction currently made to the next trial from the previous trial. Second, the correlation produced between the bias in estimation error and the actual correction was calculated. The negative high correlation suggested that a subject's estimation was used for performance correction (Blandin & Proteau, 2000). To analyze all correlation scores, Fisher's r to Z transformation was calculated, and these were used as the dependent variables which contain information on error detection and the correction mechanism.

Data Analysis A one-way analysis of variance (ANOVA), a two-way analysis of variance (ANOVA) with repeated measures on the last variables, and a three-way analysis of variance (ANOVA) with repeated measures on the last variables were used to consider the differences of |CE| and VE, and the score of error detection and correction. All significant effects are reported at $p < .05$. Post hoc comparisons of the means used the Tukey HSD technique.

III. Results

Analysis of variance (ANOVA) was employed.

Analysis of a physical practice phase The |CE| and the VE for each group were computed. To consider the acquisition level of a physical practice phase, three-way analysis of variance (ANOVA) with repeated measures on the last variable by 2 (task) x 3 (feedback condition) x 6 (block) was employed. For |CE| (Table 1), the analysis indicated the significant main effects of task ($F_{1, 66} = 164.33$, $p < .001$), feedback condition ($F_{2, 66} = 13.43$, $p < .001$), and block ($F_{5, 330} = 41.51$, $p < .001$). The results of post hoc comparisons indicated that the mean of |CE| on the free task was significantly less than that on the decided task, and that the mean of Avg 5 was more than that of 100% KR and Avg 3. Blocks 1 and 2 had a significantly larger timing errors than blocks 4 to 6. Moreover, the interaction between feedback condition and block was significant ($F_{10, 330} = 10.71$, $p < .001$). The results of post hoc comparisons indicated that Avg 5 performed more errors than 100% KR and Avg 3 on blocks 1 to 4, and that a significant change was not observed by |CE| of 100% KR. For VE (Table 2), the results of analysis showed that the main effect of feedback condition ($F_{2,\ 66} = 3.48$, $p < .05$), and block ($F_{5,\ 330} = 34.73$, $p < .001$) was significant. The mean for 100% KR was significantly less than that for Avg 5. The block main effect

Table 1 *Each group's mean and standard deviation of |CE| on each test*

Feedback condition		Experimental phase												
		Pre	Block						IT*	Retention		ITT*	RTT*	
		test	1	2	3	4	5	6		Test 1	Test 2		1	2
Free Task														
100% KR	*M*	225.0	67.8	35.8	25.6	29.0	28.3	25.3	33.6	85.3	126.0	49.5	67.3	98.0
	SD	163.9	77.3	23.2	18.3	27.5	21.9	16.8	27.3	63.4	137.5	44.2	57.8	94.4
Average 3	*M*	294.9	120.6	36.4	30.2	25.6	18.3	17.1	44.6	103.3	100.9	58.8	73.9	65.5
	SD	225.4	95.8	25.5	20.9	19.4	13.8	8.6	31.2	65.1	49.7	33.0	59.5	47.9
Average 5	*M*	317.3	257.5	95.9	66.8	64.4	42.1	37.9	45.6	91.9	108.9	60.1	41.4	62.4
	SD	189.2	159.4	87.8	49.3	39.0	31.2	27.9	33.6	50.3	58.2	37.4	34.5	44.4
Decided Task														
100% KR	*M*	262.3	98.9	76.9	60.4	59.4	77.1	62.6	70.8	87.0	133.8	95.9	92.4	101.4
	SD	165.6	95.9	69.4	51.0	54.1	66.1	60.4	60.9	78.8	104.3	56.1	65.8	83.2
Average 3	*M*	322.3	133.5	56.7	61.0	58.6	59.3	53.8	58.7	88.6	109.6	79.4	67.4	84.5
	SD	209.3	154.0	58.5	47.9	50.6	64.8	50.3	49.2	64.1	97.5	59.4	64.9	65.2
Average 5	*M*	401.1	343.0	190.0	125.5	99.6	72.6	54.9	57.7	75.5	108.6	75.6	71.5	61.2
	SD	230.6	170.2	181.6	114.5	94.4	43.4	36.4	29.2	84.3	61.7	62.4	40.8	37.9

*IT = Immediate test, ITT = Immediate transfer test, RTT = Retention transfer test.

Table 2 *Each group's mean and standard deviation of VE on each test*

Feedback condition		Experimental phase												
		Pre	Block						IT*	Retention		ITT*	RTT*	
		test	1	2	3	4	5	6		Test 1	Test 2		1	2
Free Task														
100% KR	*M*	73.4	99.8	51.0	53.4	45.0	41.2	48.3	42.9	51.4	52.9	45.7	38.0	44.5
	SD	30.0	51.5	10.8	19.9	12.7	16.6	12.5	12.1	10.9	41.4	18.4	10.4	28.5
Average 3	*M*	143.0	111.7	55.0	63.4	55.0	52.1	49.8	42.4	55.0	57.0	55.6	46.6	33.4
	SD	76.3	60.1	22.1	13.8	15.0	14.0	20.1	9.1	17.6	22.5	24.0	16.8	6.1
Average 5	*M*	97.5	140.8	71.1	91.6	70.0	67.4	58.0	58.4	67.4	69.3	54.7	56.6	61.0
	SD	37.8	83.0	22.7	58.9	29.9	30.1	18.2	19.3	19.9	30.3	19.9	25.5	27.6
Decided Task														
100% KR	*M*	111.2	90.0	70.1	79.4	79.9	68.8	59.0	51.6	62.1	60.3	46.5	48.7	50.5
	SD	62.6	43.6	31.3	33.5	19.4	27.7	21.4	20.4	39.2	21.8	18.2	14.3	23.5
Average 3	*M*	99.0	122.9	78.3	71.4	73.4	58.5	60.4	48.0	52.8	59.7	45.9	48.2	48.1
	SD	35.6	62.3	26.5	18.7	36.1	22.8	23.6	14.5	14.1	15.4	10.4	18.0	17.2
Average 5	*M*	99.3	112.8	87.9	71.2	63.4	66.2	60.3	49.2	58.1	61.0	43.5	38.6	40.1
	SD	56.5	44.7	33.9	23.9	26.2	24.6	25.9	19.9	23.2	25.5	14.0	14.0	15.2

*IT = Immediate test, ITT = Immediate transfer test, RTT = Retention transfer test.

indicated that the means for blocks 1 to 3 were larger than these for blocks 5 and 6.

From these results of analysis of the data of the physical practice phase, it could be seen that the free task led to a more accurate performance than the decided task. On the other hand, it was indicated that the learners in each condition performed with more stability. Specifically, 100% KR showed more accurate and more stable performance during the physical practice phase.

Analysis of retention tests To assess the learning effects of physical practice, a 2 x 3 x 3 (task x feedback condition x immediate test and two retention tests) ANOVA was used with repeated measures on the last variable. The main effect of the last variable was significant on |CE| ($F_{2, 132} = 25.54$, $p < .001$). The results of post hoc comparisons showed that the mean of the immediate test was the lowest of any test, and that the mean of retention test 2 was the highest of any test (Table 1). For VE (Table 2), the main effect of the last variable was significant ($F_{2, 132} = 6.39$, $p < .05$). The mean of the immediate test was less than that of retention tests 1 and 2, as seen by the results of the post hoc comparisons.

These results of the retention tests showed that there were no group on task differences. However, it was indicated that a learner's performance became inaccurate and unstable with the progress of time after physical practice.

Analysis of transfer tests To assess the effects of learning of movement parameterization over physical practice, we submitted dependent variables for the transfer tests to a 2 (task) x 3 (feedback condition) x 3 (transfer tests) ANOVA with repeated measures on the last variables. There were no significant main effects and interactions on |CE| (Table 1). The VE (Table 2) indicated that the interaction between task and feedback condition was significant ($F_{2, 66} = 4.78$, $p < .05$). The results of post hoc comparisons showed that the mean of 100% KR was less than that of Avg 5 on the free task, and the mean of the decided task was less than that of the free task on Avg 5.

The results of analysis of transfer tests showed that a learner who was given feedback after each trial performed with more stability than a learner who was given the average time of three trials on the free task, and that performance of the free task was more stable than that of the decided task for Avg 5.

Analysis of error detection and error correction To consider the mechanism of error detection and correction by physical practice, two correlation scores were computed. Then Fisher's r to Z' transformation was performed

Table 3 *Mean coefficient and standard deviation of correlation between estimated and objective error in movement parameterization*

Experimental Phase	Free Task			Decided Task		
	100% KR	Average 3	Average 5	100% KR	Average 3	Average 5
Pre test						
M	.16	.23	.19	.19	.16	.28
SD	.19	.19	.18	.28	.29	.25
Immediate Test						
M	.10	.09	.21	.15	.11	.12
SD	.24	.16	.24	.20	.18	.29
Retention test 1						
M	.24	.17	.28	.15	.24	.21
SD	.18	.21	.15	.11	.19	.11
Retention test 2						
M	.29	.14	.18	.24	.30	.22
SD	.20	.20	.22	.25	.16	.20
Immediate transfer test						
M	2.09	1.86	2.24	1.36	1.35	1.61
SD	1.59	2.39	2.18	.95	1.23	1.65
Retention transfer test 1						
M	1.18	1.97	1.85	1.34	1.59	1.09
SD	.96	1.08	1.74	1.15	1.05	.81
Retention transfer test 2						
M	1.17	1.39	1.57	1.55	1.00	2.39
SD	.98	.97	.96	1.95	.69	2.92

Note.-Score: after r to Z' transformation.

to analyze all correlation scores (Table 3 and 4).

To assess the effects of physical practice, data collected on the pretest and immediate test were analyzed with a 2 (task) x 3 (feedback condition) x 3 (test) ANOVA with repeated measures on the last variable. For the error detection mechanism (Table 3), the analysis indicated the main effect of the test ($F_{1, 66} = 4.50$, $p < .05$), and the results of post hoc comparisons indicated that the scores of the pretest were higher than that on the immediate test. For the actual correction (Table 4), there were no significant main effects or interactions.

To assess the retention tests, dependent variables for the error detection and correction were submitted to a 2 (task) x 3 (feedback condition) x 3 (test) ANOVA with repeated measures on the last variable. For the error

Table 4 *Mean coefficient and standard deviation of correction between estimated error and effective correction of movement parameterization on the following trial*

Experimental Phase	Free Task			Decided Task		
	100% KR	Average 3	Average 5	100% KR	Average 3	Average 5
Pre test						
M	−.14	−.29	−.14	−.20	−.04	−.22
SD	.21	.15	.16	.26	.26	.21
Immediate Test						
M	−.12	−.12	−.18	−.13	−.04	−.10
SD	.13	.20	.23	.18	.25	.26
Retention test 1						
M	−.10	−.05	−.25	−.17	−.15	−.15
SD	.17	.25	.16	.13	.29	.15
Retention test 2						
M	−.34	−.20	−.18	−.23	−.15	−.12
SD	.25	.16	.27	.23	.23	.24
Immediate transfer test						
M	.25	.34	.27	.42	.32	.42
SD	.24	.25	.11	.43	.19	.40
Retention transfer test 1						
M	.51	.38	.27	.40	.35	1.08
SD	.51	.28	.11	.44	.14	2.20
Retention transfer test 2						
M	.54	.27	.25	.42	.43	.44
SD	.32	.22	.12	.26	.32	.39

Note.-Score: after r to Z' transformation.

detection mechanism (Table 3), the main effect of the test was significant ($F_{2,\ 132} = 6.96$, $p < .001$), and the results of post hoc comparisons indicated that the score of the immediate test was less than that of retention tests 1 and 2. For the actual correction (Table 4), the main effect of the test was significant ($F_{2,\ 132} = 4.48$, $p < .05$). The score of the immediate test was significantly more than that of retention test 2 from the results of post hoc comparisons.

To assess the effects of learning movement parameterization over physical practice, we submitted dependent variables for the transfer test to a 2 x 3 x 3 (task x feedback condition x transfer tests) ANOVA with repeated measures on the last variable. The results showed that there were no significant main effects or interactions on the score of both dependent variables.

IV. Discussion

In this study, the influences of length for average KR and task difficulty using a barrier knock-down task (see Fig. 1) were examined. In addition, the effects of average KR on the learning of movement parameters were studied.

The results were as follows: (1) through the physical practice phase, each group's performance, especially 100% KR, became more stable. On the other hand, the free task led to more accurate performance than the decided task; (2) There were no group differences and task differences with the learning effects of physical practice; (3) In learning the movement parameter, the free task led to more stabilized performance than the decided task on the Avg 5 group, and the 100% KR led to more stabilized performance than the Avg 3 group; (4) From the results of analysis of error detection and error correction, there were no differences in mean error detection and error correction among six groups.

The results of this experiment indicated that all subjects' performance became more accurate and more stable, this tendency especially appeared on the acquisition phase of the free task. However, task effects and feedback effects were not clear from the results of the retention phase analysis and the analysis of the relationship between estimated movement time and movement time. This suggests that the effects of the average feedback method were not apparent when the timing task became more difficult. Therefore, the results showed in this experiment did not support the results of Schmidt, *et al.* (1989), Yao, *et al.* (1994), and Butki and Hoffman (2003). One possible explanation is that the task specificity in the present study led to these results because internal feedback information is required more in a barrier knock-down task than in the task used by Schmidt, *et al.* (1989), Yao, *et al.* (1994), and Butki and Hoffman (2003). Wulf and Shea (2002) pointed out that, in attempts to improve performance, the performer has to rely on sources of intrinsic feedback, because of the likelihood of the learner becoming dependent on the extrinsic feedback and neglecting the processing of intrinsic feedback is reduced if task become more complex or difficult.

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