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原　著

自己調整フィードバックはボール・パッティング学習におけるパッティング動作に作用するか？

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Does self-regulated feedback enhance putting movement in ball putting learning?

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This study examined the effects of self-regulated feedback (SRF) on ball putting and putting movements. Thirty-nine university students participated in a golf ball putting exercise and were placed under one of the three following conditions: (1) 100% knowledge-of-the-results (KR) condition (100% KR): participants practiced in the natural context, (2) SRF condition: KR was provided only when a participant demanded it; and (3) yoked self-regulated feedback condition (YSRF): KR was provided by the trial when the participants of SRF demanded it. The participants in the SRF and the YSRF conditions were unable to see the ball after putting. The results showed that SRF is effective when learning ball putting; although there were no differences in putting movement, the absolute acceleration at ball impact of SRF was more stable than the 100% KR condition.

【Keywords】self-regulated feedback, knowledge of results, putting movement

本研究は自己調整フィードバック（SRF）がボール・パッティングとパッティング動作に及ぼす影響について検討した．39 名の大学生が次にあげる 3 つの条件のうちの一つに振り分けられた：(1) 100％結果の知識（KR）条件（100% KR）：被験者は自然な状態で練習する，(2) SRF 条件：被験者は KR を要求した時に KR が与えられる，(3) くびき自己調整フィードバック条件（YSRF）：SRF の被験者が KR を要求したタイミングで KR が与えられる．SRF と YSRF 条件の被験者はパッティング後にボールを見ることができないように設定された．分析の結果，SRF にボール・パッティングの学習効果が見られた．そして，SRF のパッティング動作に変化は見られなかったが，ボールインパクト時の加速度が 100%KR 条件に比べて安定していた．

【キーワード】自己調整フィードバック，結果の知識，パッティング動作

According to the self-regulated learning theory (Zimmerman, 1989), a relationship exists between a learner's regulated learning strategies and the effects of learning. Zimmerman explained that self-regulated learning facilitates active learning with regard to metacognition, motivation, and method of learning. This theory assumes that self-regulated learners yield superior learning results because they actively use learning strategies. Wulf, Shea, and Lewthwaite (2010) indicated that self-regulated feedback is consistent with a learner's need for information about his or her performance that might serve as a motivator, such as feedback after a strategy change or after presumably successful trials.

The main purpose of this study was to examine the effects of self-regulated feedback (SRF) (participants were provided with knowledge of the results [KR] only when they demanded it) while learning ball putting. A second purpose was to analyze the changes in the participants' movements during putting. If Zimmerman's (1989) assumption is accurate, a learner using SRF will be better able to effectively use learning strategies as compared with a learner who is provided with KR, thus demonstrating differences in the learning results and behaviors. To evaluate the benefit of SRF, we introduced three con-

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ditions: (1) 100% KR condition (100% KR), where participants practiced in the natural context; (2) SRF condition, where participants were provided with KR only when they demanded it; and (3) yoked self-regulated feedback (YSRF) condition, where the participant was provided with KR by trial only when the participants of SRF demanded KR on the practice trial. The participants in the SRF and the YSRF conditions were unable to see the ball after putting because an opaque curtain was placed in front of them during the practice phase.

Employing an opaque curtain during practice might lead a learner to make his or her own estimates of putting the ball based on intuitive judgment. Perkins-Ceccato, Passmore, and Lee (2003) reported improvement in the pitch shot of a low-skilled golfer when he was instructed to self-focus by concentrating on the form of the golf swing and to adjust the force of the swing depending on the distance of the shot. Moreover, Ishikura (2008) reported that reduced relative frequency of KR while using an opaque curtain (33% KR) was effective in improving learning putting accuracy compared to the practice condition under the normal context (100% KR). Therefore, we predicted that using an opaque curtain in the practice conditions (SRF and YSRF) early in the stages of learning would improve the effects of learning as compared with a normal practice condition. If the participants in the SRF and YSRF conditions perform better than those in the 100% KR condition, then the learning effects of the practice condition with an opaque curtain will be more effective than the effects of the 100% KR condition. If the participants in the SRF condition perform better than those in the YSRF and 100% KR conditions, then this indicates that SRF facilitates the development of putting skills.

We also analyzed changes in putting movements that surface as a result of learning; we wanted to evaluate the assumption that improving motor skills, which occurs because of the learning benefits of the practice condition, is reflected in the form of changes in the learner's movements. Patterson and Carter (2010) indicated that a self-regulated practice context offers the expert the opportunity to individualize a practice for optimal challenge and effort. Patterson and Lee (2008) also predicted that the cognitive effort required for performers to self-regulate their practice environment would have important practical implications for motion experts who want to enhance their cognitive expertise in movement planning and error correction. Lee et al. (2008) examined the patterns of putting among expert and less-skilled golfers. They reported that the displacement and velocity profiles of the head and putter revealed high positive correlations for the less-skilled golfers but high negative correlations for the expert golfers. In other words, the skill level or the learning stage has an effect on fundamental differences inputting coordination modes. The second purpose of this study was to examine the changes in the displacement of the learner's head and the coordination between the learner's head and the hammerhead during putting.

Method

This experiment was conducted after obtaining approval from the Doshisha University Ethics Committee for Scientific Research Involving Human Subjects.

Participants

Thirty-nine university students (15 men and 24 women; *M* age = 20.0 years, *SD* = 1.6) participated in the study. All participants reported their right hand as the dominant or preferred hand. None had ever participated in this experiment before. Participants gave their written informed consent and received ¥1,000 in cash as remuneration for their cooperation.

Task and Apparatus

Standing in front of desks, all participants were required to putt and stop a golf ball on the goal line located 3.0 m from the standing location with a rubber hammer (Figure 1).

Procedure

Upon arrival, each participant was assigned, according to sex, to one of three conditions. The participants in the 100% KR condition (five men and eight women) performed the task in the natural practice condition; that is, they were able to see the position where the ball stopped. The participants in the SRF condition (five men and eight women) were provided with KR only when they inquired about the distance that the ball rolled. In the YSRF condition (five men and eight women), participants were provided with KR when the SRF participant inquired about the distance. For example, if the participant of SRF demanded KR on the fifth trial, then the participant of YSRF was provided KR on the fifth trial. Participants of the SRF and YSRF groups practiced with an opaque curtain lowered and were unable to see where

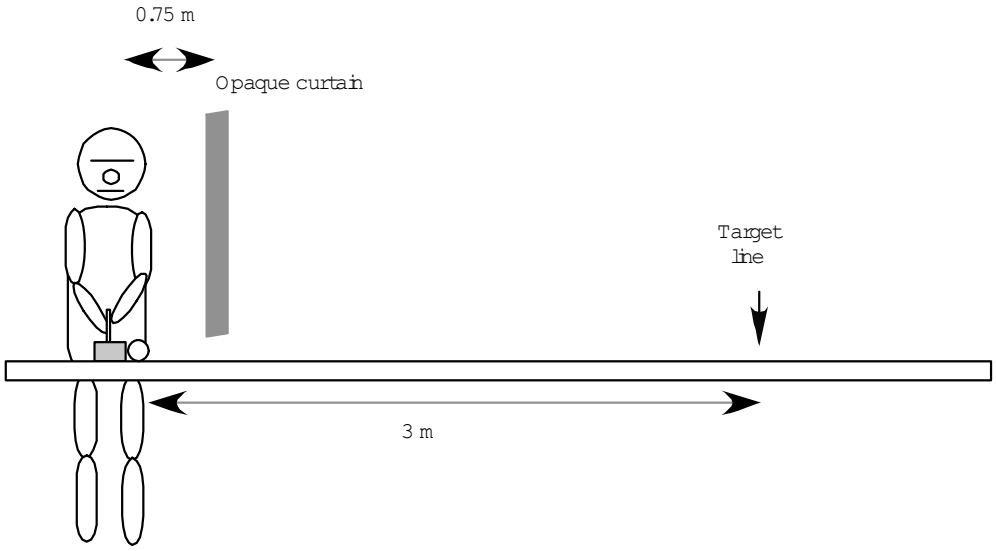

Figure 1

Figure 1. Putting task: All participants were required to putt and stop a golf ball on the goal line located 3.0 m from the standing location. The participants in the group with 100% knowledge of the results were not blind, and those in the group with self-regulated feedback practiced used an opaque curtain lowered during the practice session.

the ball stopped during practice trials. The experimenter provided verbal information about the KR to SRF and YSRF participant groups.

The experiment was conducted on an individual basis in four experimental phases. After the task and procedure of the experiment were explained to each participant, all participants took a Pretest comprising ten trials in which the participants were aware of the results (i.e., no screen); then, the participants were administered 50 practice trials based on one of the three conditions (100% KR, SRF, or YSRF). All of the participants performed the Immediate Test after the Pretest and took the Retention Test the next day. The lengths of the Immediate Test and Retention Test were the same as the Pretest (10 performance trials with KR).

Dependent Variables

The raw data were recorded as the distance (in centimetres) between the start line and the location where the ball stopped. We summarized the data from the ten trials of the Pretest, Immediate Test, and Retention Test in blocks of ten trials each. To evaluate a participant's performance on each test, we chose the constant error (CE), absolute constant error (|CE|), variable error (VE), and total variability (E) as dependent variables.

To analyze the positions of the hammerhead and the participant's head, we recorded the putting movements during the three tests at 60 frames per second with a digital video camera (DIGICAM NV-DS7; Panasonic, Tokyo, Japan). One marker was attached to the hammerhead and two other markers were attached to the brim and top of each participant's cap, which was worn during the experiment. A digital video camera was placed 3.5 m in front of each participant. Dynas 3DVer 3.5 (Shinosaka Shyokai Inc., Osaka, Japan), a type of three-dimensional motion analysis software, was used to evaluate the participants' putting movements. To evaluate the participants' head movements in each test, the data from the participants' putting movements were selected from two frames; the frame of the head of the hammer separated from the ball was selected as the beginning of the putting movement, and the frame of the ball impact was selected as the end of the putting movement. The distance covered by the head during putting and the correlation between the x-axis value (displacement trace, in meters) of the brim of the participant's cap and the head of the hammer during putting were computed. To evaluate the stability of the power given to a ball, the standard deviation of absolute acceleration of hammerhead at the ball impact was calculated. The standard of coordinates was

the golf ball, and the direction of the x-axis toward the target line was positive. The value of *r* was converted to a *Z*' score.

Analysis

We used a one-way analysis of variance (ANOVA) to assess the differences in CE, |CE|, VE, and E for the Pretest. To evaluate the effects of learning on performance and putting movement, we conducted a two-way, 3 (condition:100% KR, SRF, and YSRF) ×3 (test) ANOVA with repeated measurement of the last variable. All significant effects are reported at $P < .05$, with effect sizes reported as η^2 and statistical power reported as ϕ. We used Tukey's HSD technique to perform *post hoc* comparisons of the means, and used the SPSS 12.0.1 J (SPSS Japan Inc., Tokyo, Japan) statistical software for all statistical analyses.

RESULTS

Performance

We used a one-way ANOVA to consider the performance on the Pretest. The results showed that there were no significant differences among the three conditions for CE, |CE|, VE, and E. Table 1 shows each condition's mean CE, |CE|, VE, and E in each test.

Performance Results

For |CE| (see Table. 1), the analysis indicated a significant main effect for the test ($F_{2,72} = 5.63$, $P = .01$, $\eta^2 = 0.14$, $\phi = 0.85$). For VE (Table. 1), the main effect of the test was significant ($F_{2,72} = 22.74$, $P = .01$, $\eta^2 = 0.39$, $\phi = 1.00$) and the main effect of the condition was significant ($F_{2,36} = 6.78$, $P = .01$, $\eta^2 = 0.27$, $\phi = 0.90$). The main effect of test on E (Table. 1) was significant ($F_{2,72} = 22.69$, $P = .01$, $\eta^2 = 0.39$, $\phi = 1.00$) and the main effect of

Table 1. Group Means and Standard Deviations of Constant Error, Absolute Error, Variable Error, and Total Variability on Pretest, Immediate test, and Retention test.

Feedback Condition	Experimental Phase						Total	
	Test							
	Pre		Immediate		Retention			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Constant Error on Each Test								
100% KR	-1.38	24.16	-2.92	5.29	-0.73	14.20	-0.02	17.24
SRF	8.08	22.58	2.13	7.80	-4.84	7.93	2.03	16.30
YSRF	4.64	16.32	1.73	7.60	1.92	13.95	-0.64	16.94
Total	4.78	21.21	-2.93	12.49	-0.48	14.70		
Absolute Constant Error on Each Test								
100% KR	18.31	14.83	5.28	2.61	11.60	7.44	39.66	15.37
SRF	16.34	17.02	6.04	5.09	7.54	5.15	31.95	14.24
YSRF	14.45	7.97	15.42	12.79	10.30	9.14	42.84	13.61
Total	16.65	13.73	8.92	9.13	11.09	9.49		
Variable Error on Each Test								
100% KR	49.53	16.96	29.77	6.60	37.37	14.38	42.63	16.81
SRF	42.10	15.64	24.67	9.81	25.91	8.26	34.46	17.38
YSRF	51.52	14.49	34.62	11.82	42.37	9.03	45.96	13.71
Total	48.34	15.54	30.43	10.79	35.68	12.51		
Total Variability on Each Test								
100% KR	54.34	18.12	30.34	6.62	39.60	14.90	12.35	11.86
SRF	46.03	21.17	25.83	9.91	27.44	8.22	10.91	12.16
YSRF	54.12	14.23	39.44	13.19	44.32	9.86	13.39	10.16
Total	52.23	17.69	32.58	11.91	38.22	13.40		

Note. KR = knowledge of the results; SRF = self-regulated feedback; YSRF = yoked self-regulated feedback.

condition was significant ($F_{2,36} = 5.91$, $P = .01$, $\eta^2 = 0.25$, $\phi = 0.85$). The results of |CE|, VE, and E indicated that the value of these variables on the Immediate Test was smaller than on the Pretest. The main effect of the practice condition indicated that SRF of VE was smaller than the other conditions and that SRF of E was smaller than TSRF. CE also showed no significant differences among the practice condition, test, or their interaction.

Putting Movements

For the distance covered by the head during putting in the practice phase (Table 2), the analysis showed no significant differences among the practice conditions, tests, or their interactions.

Table 3 shows the correlations of the relative location of the participants' head with respect to the head of the hammer during putting. The analysis showed no significant differences among the practice condition, test, or their interaction.

Table 4 describes the absolute of acceleration at the ball impact. The main effect of condition was significant ($F_{2,36} = 3.24$, $P = .05$, $\eta^2 = 0.15$, $\phi = 0.58$) and post hoc comparisons indicated that standard deviation of the SRF condition was smaller than in the 100% KR condition.

Table 2. Each condition's means and standard deviations of distance covered by the head during putting on each test.

Experimental Phase	Condition		
	100% KR	SRF	YSRF
Pretest			
M	0.05	0.05	0.05
SD	0.02	0.02	0.03
Immediate Test			
M	0.05	0.07	0.06
SD	0.02	0.03	0.03
Retention Test			
M	0.05	0.07	0.06
SD	0.02	0.04	0.03

Note. KR = knowledge of the results; SRF = selfregulated feedback; YSRF = yoked self-regulated feedback.

Table 3. Mean coefficients of correlation and standard deviations of participant's head and head of the hammer during putting on each test.

Experimental Phase	Condition		
	100% KR	SRF	YSRF
Pretest			
M	0.30	0.73	0.47
SD	0.67	0.61	0.72
Immediate Test			
M	0.50	0.93	0.37
SD	0.72	0.66	0.81
Retention Test			
M	0.46	0.92	0.46
SD	0.73	0.77	0.77

Note. Score: after r to Z' transformation.
KR = knowledge of the results; SRF = selfregulated feedback; YSRF = yoked self-regulated feedback.

Table 4. Each condition's standard deviation of absolute acceleration on ball impact on each test.

Experimental Phase	Condition		
	100% KR	SRF	YSRF
Pretest			
M	16.20	6.62	8.35
SD	22.83	3.18	10.27
Immediate Test			
M	6.63	3.70	3.42
SD	2.60	1.62	1.45
Retention Test			
M	7.57	4.55	7.29
SD	2.81	2.10	9.54
Total			
M	10.13	4.96	6.35
SD	13.72	2.64	8.20

Note . KR = knowledge of the results; SRF = selfregulated feedback; YSRF = yoked self-regulated feedback.

Number of Times KRW as Demanded During the Practice Phase

The number of times a subject from the SRF group demanded KR during the practice phase was 28.5 ± 15.8 (57.0 ± 31.5%). The correlations between the participants of SRF who demanded KR during the practice phase and C, |CE|, VE, and E for the Immediate Test and the Retention Test showed no significant differences.

DISCUSSION

In this study, we examined the effects of SRF on learning ball putting and on putting movements. Since the results showed that VE and E for the practice condition with SRF were smaller than for the YSRF, our results

supported Zimmerman's (1989) findings. Additionally, although there were no noticeable differences among the three conditions of putting movements (the distance covered by the head and the head-hammer coordination) that accompanied learning, the results showed that the standard deviation of acceleration at the ball impact of SRF was smaller than that of the 100% KR condition. As Wulf et al. (2010) indicated, the participant of the SRF might adopt a strategy that provides stable power (acceleration) of the hammerhead to the ball at the ball impact on their own initiative. This strategy might influence stabled performance favorably.

Although there was no statistical difference between the conditions of the coefficients of correlation of the movements of the head and the hammer, the value of the SRF condition in the retention test was highest for all conditions. This tendency might indicate an insufficient amount of practice time. For example, Vereijken et al. (1992) reported that in initial learning trials, subjects freeze many of the joint segments of the whole body when attempting to retain balance on a ski simulator task. Hodges et al. (2005) examined this issue by monitoring the performance of a nonskilled individual learning a soccer chip shot with his nondominant leg and reported that freezing degrees of freedom (at the hip) was a strategy implemented across the first stage of the practice phase. Based on the results of this study showing that the early stage of learning was strongly correlated to the movements of the head and the hammer, it was suggested that participants in each condition froze the degrees of freedom to stabilize the putting movements. Because we did not analyze the kinematic movement in detail, we cannot draw a corroborative conclusion. In addition, Vereijken et al. (1992) and Hodges et al. (2005) reported that the subjects who continued to practice released the degrees of freedom. Further study might be required for conducting examination by increasing the number of practice trials (e.g., practice period of one month) or by considering the organization of practice (e.g., variable practice).

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