WARM-UP EFFECTS IN THE LEARNING OF DISCRETE MOTOR SKILLS[1]

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Three experiments were conducted to determine the influence of warming-up activities on performance and on learning in two discrete motor tasks. During initial trials on the criterion task, Ss were given various types of warming-up activities having an activity-set that was either the same as or different from the criterion task. Test trials followed in which all groups practiced the criterion task only. No significant differences in performance on the criterion task were found regardless of the appropriateness of the warming-up activity during initial trials. The results suggested that warming-up properties are not a factor in original learning of discrete motor skills.

The initial post-rest decrement in performance on a task that has been learned previously has generally been attributed to S's need to 'warm up', and is characterized by an extreme brevity, rarely lasting for more than the first few trials following rest. Investigations of this phenomenon in motor skills have usually involved tests of the 'activity-set' hypothesis, first proposed by Nacson and Schmidt (1971). According to this view, warm-up decrement (WU) is the result of the loss of a 'generalized' readiness (activity-set) for a given class of tasks which is supportive of the goal response yet 'neutral' in that it lends no increments of habit strength to the goal response. More specifically this hypothesis predicts that retention of the goal response should be

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greater after performance of an appropriate warming-up task inter-
polated at the end of a rest period than following trials on an inappro-
priate neutral activity. Regardless of the apparatus or limb used, the
warming-up task must be of the same class as the criterion task if WU is
to be reduced or eliminated. How narrow this class of activities is is not
specified, but it is arbitrarily assumed that the activities in a class
possess certain response requirements (such as accurate arm positioning
over trials with knowledge of results, KR), and that any positioning
response with these requirements (e.g., arm positioning, leg positioning,
etc.) is a member of the class.

Recent evidence from Schmidt and his associates (Nacson and
Schmidt 1971; Schmidt and Nacson 1971; Schmidt and Wrisberg 1971)
clearly indicates that post-rest WU in several classes of tasks can be
reduced by appropriate neutral interpolated activities. However, only
one study has been reported in which there has been a direct attempt to
measure the effects of warming-up activities on the *learning* of motor
skills. Hamilton and Mola (1953) evaluated the effect of practice on
five different finger mazes either 24 hours or immediately preceding
initial trials on a criterion maze. Since positive transfer was found for
both groups, it was reasoned that the warm-up mazes contributed
increments of habit strength rather than neutral warming-up properties
to the criterion maze. Thus, inferences regarding the effect of warming-
up in motor learning remain dubious.

The present series of experiments was designed to investigate
whether an appropriate warming-up activity practiced during initial
trials on a criterion motor task would facilitate learning of the task. A
paradigm was used in which all Ss received initial trials on the criterion
task with the principal independent variable of interest being whether S
was warmed up prior to or during these trials. After a rest, Ss were then
given test trials on the criterion task only, to determine whether
warming-up activities had affected learning.

Experiment I

Method

Subjects

Right-handed male and female graduate and undergraduate students at the University of
Michigan (N = 40) served as Ss in Exp. I. None was paid for his or her services.

Right-hand task apparatus

A hand-grip device modified from a hand dynamometer was fastened to a 91.4 cm long, 5.1 X 30.5 cm wooden stand bolted to a desk 81.3 cm high. A cable connected the hand grip to a strain gauge which when stretched produced a signal which was amplified by a four-channel amplifier and output on a meter. The force was scaled in units from 0 to 100 with a reading of '50' representing a force of 15 lb. Thus, each scale unit was equivalent to 0.3 lb of force.

Left-hand task apparatus

A cable running through four pulleys connected a handle to the same strain gauge as used in the right-hand task. Running down the front of the desk to a pulley on the floor, the cable was directed horizontally to the rear of the desk. From there two more pulleys directed the cable diagonally upward to a final pulley at the top rear of the desk which sent it to the strain gauge. The handle and hand-grip device were located so that S could operate them both from the same seated position.

Procedures

Ss were randomly assigned to one of two conditions with the restriction that each condition have 20 Ss. Following a description of the right- and left-hand tasks, S was given one familiarization trial on the right-hand task, squeezing slowly and carefully and observing the response of the meter. The meter was then turned so that it could be viewed only by E and five practice trials on the right-hand task (at a different force from that used in the experiment) were given to screen those Ss unable to squeeze to within ± 10 units of the practice force (70 units). If there were no questions, the experiment was begun after a one-minute rest.

The command 'Ready' was always followed in 2 sec by 'Squeeze' for the right-hand task. When S felt he had achieved the required force, he said 'There', holding the force until E recorded the score and reported it to S in units. Between trials (15 sec) S relaxed his hand completely, waiting for the next 'Ready' command in response to which he engaged the apparatus and removed any slack in the cable. All Ss received 5 initial right-hand trials, a rest of 10 min, and then 10 test trials on the right-hand task.

The principal independent variable was the temporal location of a 5-trial block of left-hand warming-up trials during the 8-min interval prior to initial right-hand trials. The activity-set condition (AS) received 5 left-hand trials at the end of this interval while the control condition (C) received 5 left-hand trials at the beginning. Since activity-set reinstatement has been found to be negated when as many as 40 sec are interpolated between the warming-up activity and practice on the criterion task (Schmidt and Nacson 1971), only Condition AS which received left-hand practice immediately prior to initial right-hand trials was expected to profit from the warming-up activity. In both conditions, the warming-up force to be estimated with the left-hand was 5 lb (i.e., 20 units) and KR was given in units. By learning to estimate a specific force with KR but without vision of the meter, S was performing a task with the same activity set as the right-hand task but, as has been demonstrated by Nacson and Schmidt (1971), is neutral with respect to the right-hand task habit since it involves the opposite limb and different musculature.

Preceding each block of trials on either task Ss were instructed as to the force they should be attempting to estimate. Although performance on the right-hand task was the principal measure of interest, Ss were told that they should be trying to learn both right- and left-hand

forces. This precaution seemed important for two reasons. First, in order to make inferences about learning it was important that a learning set be instated. Since the warming-up effect during *initial* learning was the issue, a learning set could not be instated through accumulated experience (e.g., Harlow 1949). Therefore instructions to learn were reasoned to be the primary way of promoting the learning set. Furthermore, in light of an investigation by Adams (1955) which revealed post-rest decrement in rotary pursuit performance to be reduced *only* for Ss forced to attend to a secondary task during the interpolated period, it was reasoned that by equally emphasizing right- and left-hand tasks in the present experiment, an accurate estimate of the effects of warming-up activities on learning could be obtained.

Results

Table 1 summarizes variable error (VE) and constant error (CE) for five-trial blocks during both initial and test trials on the right-hand task. While all Ss demonstrated considerable performance gains with practice, differences between groups were small for both initial and test trials. On initial trials, the Conditions effect failed significance for both CE and VE $F(1, 36)$ = 1.35 and $F(1, 36)$ = 1.81, $p > 0.05$, respectively. The Conditions comparison on the test trials yielded similar results, $F(1, 36)$ = 1.35 and $F(1, 36)$ = 0.11, $p > 0.05$, respectively, thus failing to provide support for the prediction that an appropriate neutral warming-up activity practiced immediately prior to initial performance would facilitate learning of the task. There was some indication that temporal location of the left-hand task in the interval preceding initial trials affected CE. While not significant, Condition AS demonstrated a 1-lb greater positive CE (i.e., overshooting) than the control condition on initial trials.

One possibility for the lack of differences was that the warm-up effect did not persist throughout the entire block of initial trials. Recent evidence (Godwin and Schmidt 1971) has suggested that a performance variable (e.g., fatigue) may also affect learning if manipulated vigorously during pre-rest practice. With this in mind, Experiment II was conducted using a paradigm in which Ss were warmed-up prior to *each* initial trial on the right-hand task in order to minimize the possibility that the benefits of warming up might dissipate before the block of initial trials was completed.

Table 1
VE and CE (lb.) for the 5-trial blocks of initial (block 1) and test (blocks 2 and 3) trials on the right-hand task in Experiment I.

Condition	VE Block			CE Block		
	1	2	3	1	2	3
AS	3.78	2.78	1.88	1.66	1.30	0.35
C	3.14	2.82	1.66	0.43	0.89	−0.15

Experiment II

Method

Subjects

Right-handed male and female graduate and undergraduate students at the University of Michigan (N = 45) served as Ss in Exp. II. None had had previous experience in a force-estimation experiment and none was paid for his or her services.

Apparatus and task

Both apparatuses were identical to those used in Exp. I. The commands to Ss, the target locations, and the nature of KR following each trial were the same as well.

Procedures

Ss were randomly assigned to one of three conditions with the restriction that each condition have 15 Ss. The following features distinguished Exp. II from Exp. I: (i) The initial right-hand trials were increased from 5 to 25 in order to give Ss more opportunities to delineate the nature and demands of the task; (ii) test trials on the right-hand task were increased from 10 to 15; (iii) the number of conditions was increased from 2 to 3 with a control condition (C) given no warm up during initial trials and a maximum pull condition (MP) receiving left-hand trials which required a maximum effort; and (iv) 3 trials on the left-hand task (Conditions MP and AS only) preceded *each* of the 25 initial right-hand trials. It was reasoned that in addition to instating an inappropriate activity-set for the right-hand task (i.e., maximum pulls rather than slow, careful pulls to a designated level), the MP Condition would provide a case wherein decreased performance on initial trials, and hence decreased learning on test trials, of the right-hand task would be evidenced. As in Exp. I, Ss were told that both right- and left-hand forces were equally important. Following initial trials and a 10-min rest, all Ss were given 15 test trials on the right-hand task with a 15-sec intertrial interval filled only by rest; these trials served as the measure of learning.

Results

VE and CE for blocks of initial and test trials on the right-hand task are summarized in table 2. As in Exp. I, there were no significant differences in CE among Conditions either on initial or test trials, $F(2,44) = 1.44$ and $F(2,44) = 1.26$, $p > 0.05$, respectively. VE on trials 6–25 revealed significant differences among Conditions, $F(2,44) = 7.30$, $p < 0.05$, but the ordering of VE was contrary to that expected. Of the three conditions, C displayed the lowest VE, MP was intermediate, and AS was highest. Therefore, rather than providing Ss an advantage, it appeared as though activity-set instatement (AS) induced decrement in force-estimation per-

Table 2
VE and CE (lb.) for the block of initial (10 trials) and test (15 trials) trials on the right-hand
task in Experiment II.

Condition	VE Block		CE Block	
	1	2	1	2
AS	3.51	2.87	0.46	0.61
C	2.24	2.00	−0.26	0.23
MP	2.95	2.45	0.23	0.19

formance. On the block of test trials, there was no significant difference in VE among
Conditions, $F(2, 44) = 2.17$, $p > 0.05$, indicating that the effect found during initial trials was
only temporary.

While CE for Condition MP during initial trials was not significantly greater than that of the
other groups, an analysis of the first five right-hand trials revealed that CE was an increasing
function of the amount of force exerted, (i.e., C = 3.93; AS = 10.96; MP = 12.76) $F(2, 44) =$
3.03, p = 0.05. This suggested that at least on early trials of force estimation learning intensity
as well as temporal placement of the warming-up activity may be a variable affecting CE.

Experiment III was conducted to determine whether the failure of appropriate warming-up
activity to influence learning in Exp. I and II was limited to tasks of force estimation. In
Exp. III, a movement-speed task was used.

Experiment III

Method

Subjects

Right-handed male and female graduate and undergraduate students at the University of
Michigan ($N = 68$) served as Ss in Exp. III. None was familiar with the apparatus and none was
paid for his or her services.

Right-hand task

The task was the Sigma task (see Godwin and Schmidt 1971; Schmidt and Wrisberg 1971),
so named because of the σ-shaped movement of the hand which was required. It consisted of a
handle (11 cm high and 2.6 cm thick) mounted vertically on the end of a horizontal 22 cm
aluminum lever. The opposite end of the lever was attached to a vertical axle which ran in a
bearing firmly mounted in a wooden box-like structure (30 × 49 × 10 cm) so that the lever was
free to rotate in the horizontal plane. A sturdy metal stop positioned on the edge nearest S

allowed movement through only 344 deg. On another edge of the box 43 cm from the axle was a padded masonite barrier (10 cm square) fastened with a hinge so that a slight tap was sufficient to cause the barrier to fall. The box was mounted securely to a large table 76.2 cm high.

In this task, S began with the apparatus in the starting position, with the handle against the stop and the barrier upright. S was seated in a straight- backed wooden chair positioned so that the handle, when against the stop, was at his midline. On the command 'Ready' from E, S grasped the handle firmly. On the command 'Go' which always came 2 sec later, S moved the handle clockwise (i.e., initially to his left) 344 deg. until it struck the metal stop, then reversed his direction to return the handle to the starting position. When the handle struck the stop again, he released it and moved his hand to the right 43 cm to knock over the padded barrier. The task was to make this defined movement as quickly as possible. Moving the handle to the left initially started a 0.1-sec timer (Standard, Type S–1, 6–V. dc clutch) and knocking over the barrier stopped it; thus, the score was the total time required to complete the defined movement consisting of two circular phases and a linear phase. Reaction time was not measured.

Left-hand movement task

The apparatus consisted of a wooden board (46 × 60 × 2.5 cm) mounted on the table to S's left of the right-hand apparatus. Mounted on the surface were (a) a start button which operated a microswitch, (b) a 'dummy' doorbell-type push button, and (c) a 10 cm square masonite barrier attached with a hinge. This task, demonstrated by Schmidt and Wrisberg (1971) to have an activity-set similar to the Sigma task, also required a rapid limb movement. S was seated in the same chair but was rotated 90 deg. to his left so that he was facing the left-hand task apparatus. On the command 'Ready' S depressed the start button with his left index finger, and 2 sec later on the command 'Go' S removed his finger from the start button, moved forward to press the dummy button, and then to the right to knock over the barrier, the movement being done as quickly as possible. Releasing the start switch started the timer and knocking over the barrier stopped it; thus, the score was the total time to complete the two-part movement. As in the right-hand task, reaction time was not measured.

Left-hand accuracy task

On a 21.6 × 17.9 cm piece of paper were mimeographed six small tracing mazes 5 cm long with a track width of 0.32 cm. Each maze was identical, requiring five directional changes for completion. The mazes were arranged in two rows with three mazes in each row. This task required careful left-hand tracing. Ss performing this activity were rotated 90 deg. to their left as in the left-hand movement-speed task. On the command 'Ready' S grasped a pencil 9 cm in length with a clenched left fist, and placed the pencil at the beginning of the first maze. On the 'Go' command which always followed 'Ready' by 2 sec, S began navigating the maze attempting to stay within the lines. Ss were told that error-free completion of the maze was worth 5 points, error-free incompletion was worth 3 points, and error trials (going outside the boundaries) were worth 0 points.

Procedures

Ss were randomly assigned to one of four conditions with the restriction that each condition have 17 Ss. On Day I, Conditions AS (left-hand movement-speed task) and AC (left-hand accuracy task) received 6 trials on their respective warming-up tasks prior to *each* of 10 initial right-hand Sigma trials. A long-rest control condition (LR) rested during the 1 min prior to each initial trial on the Sigma task while a short-rest condition (SR) received an unfilled intertrial interval of 15 sec. KR in the left-and right-hand movement-speed tasks was given in 0.01 sec while in the left-hand accuracy task it was given in points. As in Exp. I and II, Ss were told that they should be trying to learn *both* right- and left-hand tasks. On Day II, all Ss received 10 Sigma test trials separated by a 15-sec intertrial interval filled only with rest. These Day II right-hand trials provided a test of the effect of Day I treatments on learning. If an appropriate warming-up activity was a factor during initial right-hand trials, then Condition AS should have demonstrated superior performance on Day II.

Results

Sigma-task movement times for 10-trial blocks of initial and test trials are shown in table 3. Both the Conditions effect and the Conditions by Trials interaction for Day 1 performance failed significance, $F(3, 64) = 0.16$ and $F(27, 576) = 1.32$, $p > 0.05$, respectively. On Day II with all conditions switching to the same right-hand task practice, lack of differences persisted both for Conditions $F(3, 64) = 0.92$, $p > 0.05$, and Conditions by Trials, $F(27, 576) = 1.33$, $p > 0.05$, lending no support to the idea that in a class of skills requiring high rates of limb movement speed, practice on an appropriate warming-up activity prior to each initial trial on the criterion task will aid learning.

Table 3
Movement time (sec.) for 10-trial blocks of initial (block 1) and test (block 2) trials on the right-hand task in Experiment III.

Condition	Block 1	2
AS	1.48	1.23
AC	1.46	1.21
LR	1.50	1.21
SR	1.52	1.33

Discussion

The obvious result of the present series of investigations is that opposite-hand warming-up prior to or during initial trials on a discrete motor task does not enhance learning. In all three experiments, condi-

tions receiving appropriate warming-up activities during initial trials on the right-hand task failed to demonstrate a significant superiority on test trials separated by rest only.

The dependent measures used suggested, however, that warming-up activities were not entirely without effect. In Exp. II, the significantly greater VE for condition AS on initial right-hand trials indicated the possibility that attention to the demands (e.g., KR) of more than one task might be a critical variable. Since these Ss performed alternately on left- and right-hand tasks, it is reasonable to assume that full attention may have been diverted from the right-hand task thereby negating some of the positive effect of warming-up.

In Exp. I and II in which a task of force estimation was used, there were consistent CE trends during initial right-hand trials. The more intense the warming-up activity (Exp. II) and the closer its proximity to performance on the right-hand task (Exp. I), the greater was the positive shift in CE. Thus, it appeared that during initial right-hand force-estimation trials in Exp. I and II, opposite-hand warming-up activity shifted CE on the criterion task in a way similar to same-hand interpolated activity in the motor short-term memory experiments of Pepper and Herman (1970).

In conclusion, the results of the present series of experiments seem to indicate that warming Ss up prior to or during initial trials on a criterion task will not facilitate learning of the task. Such findings are opposite those of earlier studies which used *already-learned* criterion tasks and reported temporary reductions in post-rest decrement (i.e., WU) when warming-up activities were practiced at the end of interpolated rest intervals (Nacson and Schmidt 1971; Schmidt and Nacson 1971; Schmidt and Wrisberg 1971). Thus, it appears that while warming-up properties are a factor in well-learned tasks, they are without effect in the acquisition of motor skills.

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