FURTHER TESTS OF THE ACTIVITY-SET HYPOTHESIS FOR WARM-UP DECREMENT

RICHARD A. SCHMIDT
Department of Physical Education, University of Michigan

AND

JACQUES NACSON
Columbia University Department of Physical Education, Teachers College

Two experiments tested the activity-set hypothesis for warm-up decrement (WUD) in motor tasks, which states that WUD is due to loss of adjustment of essential mechanisms (the activity set) over short periods of no practice. Twenty trials of a linear positioning task (right-hand) were followed by a 10-min. rest with activities designed to either reinstate the lost activity set or to interfere with the reinstated activity set. Ten additional trials were given on the right-hand task, and WUD was measured on the first trial. A left-hand positioning task immediately prior to the resumption of right-hand practice greatly reduced WUD relative to a resting control condition, tapping (right-hand) or grip strength (left-hand) tasks after the left-hand positioning task increased WUD, and greater intervals from the end of the left-hand task to the right-hand task increased WUD. These findings supported three predictions from the activity-set hypothesis and supported the hypothesis that WUD is the loss of adjustment over rest of underlying central response mechanisms.

When Ss practice a task for a number of trials and then are allowed to rest, the performance on the first few trials following the rest is nearly always depressed somewhat. This decrement has been thought to be due to the "need to warm up" and has been termed "warm-up decrement" (WUD). Due to the generality of the phenomenon, it has been the subject of considerable research, and a number of hypotheses have been advanced to explain it (see Adams, 1961). The most important of these has been the "set" hypothesis, first proposed by Irion (1948), which states that the decrement in performance is due to loss of a state (set) which is supportive of the goal response, but is not related to the habit strength for the response. This set is thought to consist of "an aggregation of postural and attentive adjustments [Irion, 1948, p. 338]" and various learned secondary responses, "such as the orientation pattern for visual receptors, proper postural attitudes, and muscular tensions [Adams, 1961, p. 262]."

Support for the set hypothesis has been mixed. In verbal behavior, Irion and Wham (1951) showed that Ss who engaged in color naming prior to recall of paired associates showed greater retention (and presumably less WUD) than did Ss who simply rested, but a number of other investigators have failed to replicate these findings (e.g., Hovland & Kurtz, 1951; Lazar, 1967; Rockway & Duncan, 1952; Whithney, Buxton, & Elkin, 1949). In motor behavior there have been attempts to reinstate the lost "set" in a manner analogous to that of Irion (1949), but "neutral" tasks have not been found which will reinstate the set (e.g., Ammons, 1951; Hamilton & Mola, 1953; Walker, Desoto, & Shelley, 1957). Exceptions are Adams (1955) and Rosenquist (1965), who showed that Ss who, during a rest period, watched a partner perform on the pursuit rotor and who made a finger response when the partner was judged "on target" produced less WUD on subsequent pursuit rotor practice than did Ss who simply rested, and the implication was that the watching activity reduced the decrement in the visual following response. Also, Barch (1963) showed that Ss who transferred immediately from left- to right-hand practice on the pursuit rotor showed less WUD on right-hand practice than did Ss who waited 24 hr. before transferring, but

1 Requests for reprints should be sent to Richard A. Schmidt, Department of Physical Education, University of Michigan, Ann Arbor, Michigan 48104.
Spatz and Irion (1969) have failed to replicate Barch's findings. Thus, the fact that the set hypothesis has received only minimal support has led to a search for additional mechanisms.

Although it is possible that the experiments which have tested the set hypothesis have not provided fair tests of the set view, a more likely possibility is that the basic nature of the hypothesized set may be wrong. Although the exact nature of set is not completely clear in the descriptions by Irion (1948) and Adams (1961), it does seem clear that set is seen as a series of adjustments which are closely related to the criterion task and/or apparatus. Adams' (1961) mention of postural attitudes and muscular tensions clearly refers to adjustments appropriate only for a given task. Irion's (1948) mention of "attentive adjustments" is not as clear, but probably refers to S's orientation of receptors to receive the important stimulus elements in the task, and Adams' (1961) mention of the "orientation of visual receptors" (e.g., the eye movement response in rotary pursuit) is in keeping with this view. A second line of thinking which supports the specific nature of "set" is that the tests of the set hypothesis have always been conducted to reinstate a set which is specific to the task, such as the eye movement response in the pursuit rotor, the rhythm of responding in color naming, etc. Because the rather specific set does not appear to account for WUD, a more generalized state (an "activity set") was proposed by Nacson and Schmidt (1971).

The Nacson-Schmidt (1971) activity-set hypothesis states that the decrement in performance following a period of no practice is due to the loss of a generalised readiness to respond rather than to the loss of the specific state defined by the set hypothesis. It is assumed that S has a number of supportive mechanisms which underlie the performance on any motor task and that these systems are adjusted by S so that they contribute maximally to the desired performance. For example, the activation (or arousal) system must operate at some optimal level, as Martens and Landers (1970) and others have shown that both too little and too much activation can lead to decrements in performance. Also, S must adjust his expectancies for up-coming events, with such expectancy effects easily shown in RT situations (e.g., Gottsdanker, 1970). Depending upon the objectives of the task, S will adjust the relative importance of speed and accuracy, with such effects being shown by numerous investigators (e.g., Fitts, 1966). When S has practiced the task for a number of trials, the mechanisms independently attain adjustments appropriate for that activity, and this delicate adjustment defines the activity set, so termed because it is appropriate for a number of activities of a given class (i.e., with common response requirements). Thus, one might speak of an activity set for blindfolded positioning, and this activity set would be appropriate for any blindfolded positioning task (e.g., leg or arm positioning). Also, when the response requirements change (e.g., by adding vision), a new activity set is defined for the second class of tasks and, subjectively, it seems reasonable that the activity set for threading a needle would be different from that for attaining maximum grip force. If S is allowed to rest, the activity set is lost, either by decay or by a process analogous to interference in which the activity set is replaced by another (possibly that for efficient resting), and S cannot perform well until it is reestablished. Since this reinstatement cannot occur immediately, the decrement is quickly eliminated in the next few practice trials.

At first sight, the set and activity-set hypotheses might appear similar, as both use nonhabit internal states which underlie the response. However, the major distinction is that set is seen as being related only to the specific task or apparatus for which it was established and need not be appropriate for a second task with similar response requirements (but different apparatus), while the activity set is appropriate for the task in question as well as any other task with the same response requirements, regardless of the apparatus and limbs used. For example, the set instated
for blindfolded linear positioning with the right hand need not be appropriate for blindfolded linear positioning of the leg, since postural adjustments and specific stimuli are different for the two tasks. However, the activity set for the right-hand task is appropriate for any positioning task with the same response requirements. This, then, is the basis for the fundamental prediction of the activity-set hypothesis, namely, that instating an activity set for a given class of tasks will reduce WUD on any other task of the same class, regardless of apparatus and limb used. The set hypothesis could not make this prediction, as postural adjustments and stimuli might be different within a class of tasks.

Nacson and Schmidt (1971) found support for this prediction in three experiments using force estimation or linear positioning as criterion tasks. During a 10-min. interpolated no-practice period, left-hand tasks of the same class (requiring the same activity set) were introduced (i.e., left-hand force estimation and left-hand positioning), and immediate transfer to the right-hand task eliminated the decrement for force estimation and greatly reduced it in linear positioning. Since the left-hand tasks used different apparatus, movement directions, and criterion forces and distances, the results could not be attributed to reinstatement of set or to the bilateral transfer of the memory trace. Appropriate control conditions ruled out the activation hypothesis, and a third experiment ruled out possible motivating effects of KR provided in the interpolated activities.

The present experiments were designed to test two additional predictions of the activity-set hypothesis which state that (a) interpolated activities of a different class than the criterion task will instate an inappropriate activity set and increased WUD should result on subsequent criterion task practice and (b) increasing the interval following the end of the reinstatement task will allow the activity set to dissipate and produce increased WUD.

**Experiment I**

**Method**

**Subjects.**—The Ss were 60 male, right-handed graduate and undergraduate students at the University of Maryland. None were paid for their services.

**Apparatus.**—The apparatus was the same as used in Nacson and Schmidt (1971, Exp. II and III). The criterion task apparatus consisted of a handle which could be moved horizontally along two 5-in. stainless steel rods (48 in. long) on ball bearings (Thompson Ball-Bushings). A pointer was attached to the slide which referred to a meter stick mounted under the rods. The apparatus was mounted on a base which was secured to a standard wooden table 23 cm. from one side. A straight-backed arm chair for S was positioned so that the midline of the chair “intersected” the rods 27 cm. from the right-hand end.

The interpolated task apparatus was mounted on the same base as the criterion task apparatus, but consisted of a heavy iron block (1 X 2 X 4 in.) which could be slid horizontally along a stainless steel surface guided by an aluminum edge along one side. The direction of travel was parallel to the rods in the criterion task apparatus. A meter stick was mounted on one side and indicated the distance the block had traveled from a stop at the left end of its travel.

**Criterion task.**—The criterion task was linear positioning, in which S was to learn a particular location along the rods (50 cm. from the right end.) The blindfolded S was seated with the chair in the standard location, with the rods running perpendicular to the direction he was facing. On the command “Grab” S reached his right hand forward and to the right to grasp the handle, and on the command “Move” he moved the handle to the left until it contacted a heavy metal stop, and this defined the position to be learned. On the command “Release” S released the handle and E moved the handle to the starting position at S’s right and removed the stop. Then on the command “Grab” (5 sec. after “Move”) S again grasped the handle, and on the command “Move” S attempted to replace the handle in the defined location without the aid of the stop. When S felt that he had achieved the correct location, he gently released the handle. Knowledge of results (KR) was then given in terms of the direction and amount (in mm.) of error (e.g., “long 26”). Then the commands “Grab” and “Move” were provided for the next trial, with S moving to the defined location on this and all subsequent trials without the aid of the stop. The interresponse interval (i.e., from “Move” to “Move”) was constant at 10 sec., and KR was given after each trial.

**Interpolated task.**—The interpolated task (when used) involved positioning S’s chair so that he was facing 90° to the right of his placement in the criterion task. This placed the interpolated task apparatus on S’s left, with the direction of block...
travel being forward–backward. Using the same commands as for the criterion task, S was told to grasp the block and to move until he struck a stop which defined the position to be learned. He then released the block, E returned it to the starting position, and S was then told to grasp and move again, this time to reposition the block to the defined location without the aid of the stop. KR was provided in the same manner as for the criterion task, and S performed 18 trials of the interpolated left-hand positioning task with KR after every trial and a 10-sec. intertrial interval.

**Design.**—All Ss received 20 trials of the criterion task, followed by a 10-min. period of no criterion task practice, followed by 10 additional trials on the criterion task, and the experimental variable was the nature of activities provided during the 10-min. no-practice period. The Ss were assigned at random to one of four treatment groups, with the restriction that each group have 15 Ss. Group REST simply rested and read magazines outside the test room for the entire 10-min. period. Group AS (activity-set reinstatement) practiced the left-hand positioning task (18 trials) during the last 3 min. of the interpolated period, and Nacson and Schmidt (1971, Exp. II and III) showed that this treatment greatly reduced WUD over the REST condition. Group AS + T (activity-set reinstatement plus tapping) performed 18 trials of the left-hand positioning task, but began 40 sec. before Group AS (i.e., at 6:20 of the interpolated period). During the last 40 sec. of the interpolated period, Group AS + T performed a simple tapping task, in which a pencil was tapped successively in three targets arranged in an equilateral triangle. The tapping time was 5 sec., and S tried to tap as rapidly as possible. After each tapping trial, S received KR (the number of taps made), and then another trial was administered until 4 trials were completed. This tapping activity was designed to instate an activity set inappropriate for positioning (but appropriate for tapping), and this activity should nullify the effect of the left-hand positioning task. A fourth group, Group AS + R (activity-set reinstatement plus rest), was used to control for the possibility that any increase in WUD for Group AS + T over and above Group AS was not simply due to the 40-sec. interval, and the procedures for Group AS + R were identical to those for Group AS + T, except that the tapping task was not administered, Ss simply resting during the last 40 sec. of the interpolated period.

Following the end of the 10-min. interpolated period, all Ss returned to the criterion task for 10 additional trials. In all treatment groups, Ss repositioned the chair to the appropriate position in approximately 5 sec. and began practicing the criterion task as before, with the first trial presented without the aid of the stop. The intertrial interval was 10 sec., and KR was provided after each trial, as before the interpolated period.

**Results**

The performance curves for the prerest and postrest performance on the criterion task (absolute error) are shown in Fig. 1. Following the 10-min. interpolated period there were considerable among-groups differences, especially on Trial 21. In analyzing Trial 21 scores, large heterogeneity of variance was present, with Group AS + T having considerably greater variability than all other groups and Group AS displaying least variability. As a result, a square-root transformation (Edwards, 1960, pp. 128–130) was performed on Trial 21 absolute error scores. Group REST exhibited considerable WUD on Trial 21, which was in agreement with other experiments using these tasks, but Group AS, which had the left-hand positioning task immediately prior to the right-hand task, showed markedly reduced WUD on Trial 21. Using planned comparisons (Hays, 1963, pp. 464–466), the contrast between Group REST and Group AS was significant, \( t(56) = 2.06, p < .05 \), and this provided a direct replication of the Schmidt-Nacson (1971) findings. Group AS + T demonstrated considerably greater WUD on Trial 21 than any other group, and when Group AS + T was compared with Group AS + R to determine the effects of the tapping activity unconfounded by differences in the post-left-hand activity interval, the contrast was significant, \( t(56) = 2.24, p < .05 \), indicating that the tapping activity produced greater WUD than simply resting for the same length of time. Finally, allowing Ss to rest 40 sec. after the left-hand activity (Group AS + R) appeared to nullify the effects of the left-hand task, since Group AS + R showed considerably greater WUD than did Group AS and even slightly greater WUD than Group REST. The contrast between Groups AS + R and AS was significant, \( t(56) = 2.13, p < .05 \), and indicated that a 40-sec. rest was sufficient to increase WUD to a point comparable to a group which never had the left-hand activity. The same basic analysis, without the square-root transformation, was conducted.
Fig. 1. Mean absolute error for the right-hand positioning task before and after the interpolated treatments (Exp. 1).
for algebraic errors, but the means showed no consistent pattern, and none of the contrasts mentioned above reached significance.

**Discussion**

Three major points come from the data. First, the differences between Groups AS and REST replicated the earlier findings of Nacson and Schmidt (1971). The interpretation is that the left-hand task, being of the same class as the right-hand task (i.e., positioning), reinstated the lost activity set which was then available for the right-hand task. The fact that the left-hand task used a different apparatus, movement direction, limb musculature, etc., argues against an explanation either in terms of set or transfer of the memory trace from left to right. Second, the activity set appears to be very easily lost over short rest periods of 40 sec., and Group AS + R even demonstrated slightly greater WUD on Trial 21 than did Group REST, which never had the left-hand activity. Third, at least a portion of the activity-set loss appears to be by replacement rather than by decay, since the tapping activities produced very large WUD on Trial 21 relative to all other groups. The interpretation is that tapping caused Ss to adopt an activity set appropriate for tapping and, since tapping is seen as being a member of a different class than positioning, the activity set for tapping is inappropriate for positioning and results in very large errors when this activity set is in force. However, the last line of reasoning about replacement is equivocal, since the tapping task was executed with the same hand as the criterion task, and it could be argued that tapping simply caused fatigue of the local musculature, or interfered with joint receptors, etc., and that the differences due to tapping might not be attributable to an appropriate activity set. Because of this fact, a second experiment was conducted with interpolated activities done with the left hand so as to rule out explanations in terms of fatigue-like effects of the right-hand activities.

**Experiment II**

**Method**

**Subjects.**—The Ss were 18 male and female graduate and undergraduate student volunteers at the University of Michigan. There were 7 males and 11 females, and none were paid for their services.

**Apparatus.**—The apparatus, in terms of the components, the locations of the apparatus on the table, and position of S's chair with respect to it, was the same as that used for Exp. I. The only differences in apparatus between the two experiments were the testing room and table and chair used.

**Tasks.**—The criterion and interpolated tasks were identical to those used in Exp. I. The commands to S, the target locations, the nature of KR following each trial, and the intertrial interval (10 sec.) were identical as well.

**Design.**—As with Exp. I, 20 trials of the right-hand criterion task were presented, and this was followed by a 10-min. interpolated period of no practice in which the experimental treatments were administered. One treatment (REST) involved resting and reading magazines outside the test room for the entire 10-min. period. A second treatment (AS + R) was analogous to that provided for Group AS + R in Exp. I, in that 18 trials of the left-hand task were administered starting at 6:35 of the interpolated period, and this practice (3 min.) was followed by a 25-sec. rest. During this 25 sec., S stood up, turned his chair (with E's guidance) to the location required for the right-hand task, adjusted himself in the chair, and waited for E's command "Grab" for the right-hand task. A third treatment (AS + G) also started at 6:35 of the interpolated period, and this involved 18 trials (3 min.) of left-hand practice followed by 25 sec. filled with the following events: Following the last left-hand trial, S was instructed to grasp a hand-grip dynamometer with the left hand, and, on E's command, to squeeze the device as hard as possible, releasing on E's command. The KR was then provided in terms of the amount (in kg.) of force produced by S, and then E instructed S to squeeze again, this trial also being followed by KR. Then S stood up, turned his chair, positioned himself carefully in it, and grasped the handle of the right-hand task on E's command "Grab." Following the 10-min. no-practice period, all Ss were administered 10 additional trials on the right-hand task as in Exp. I.

A repeated-measures design was used in which each S participated in each of the three treatments, but in a balanced order. Each of the six permutations of the three treatments had Ss randomly assigned to it, with the restriction that each permutation has exactly three Ss. All Ss practiced the initial 20 trials, followed by the three consecutive treatment sessions, each of which consisted of a 10-min. no-practice interval and 10 additional trials of the right-hand task, and each treatment session was one of the three treatments administered in the balanced order described above. Following the last trials of right-hand practice session, S removed his blindfold and E explained the nature of the activities for the next no-practice period. When E was sure that S understood what he was to do, he was asked to leave the room and to rest and read magazines for the remainder of the no-practice interval.

**Results**

The performance curves for absolute error for all practice trials are given
Fig. 2. Mean absolute error on the right-hand positioning task for the initial 20 trials and for the 10-trial blocks following the experimental treatments (Exp. II).

in Fig. 2. The prerest trials give the performances on the first 20 trials for all 18 Ss. The postrest curves also are each based upon 18 Ss, but the performances following the various treatments are plotted separately. All treatment conditions showed considerable WUD following the interpolated treatments. The effects of the various treatments were analyzed by planned comparisons (Hays, 1963, pp. 464–466) as in Exp. I, and the contrasts studied were (a) the difference between the REST and AS + R treatments as an indication of the loss in activity set over the 25-sec. interval after the left-hand activity, and (b) the difference between the AS + R and AS + G treatments as a measure of the effect of the hand-gripping activities. Treatments REST and AS + R produced very similar results for the first few trials postrest, and the comparison between these two treatments was not significant, with \( t (34) = .54, p > .05 \). This indicated that the 25-sec. rest period following the left-hand activity was sufficient to nearly nullify the beneficial effects (shown by Group AS in Exp. I) of the left-hand practice, and these findings supported those of Exp. I concerning the difference between Groups REST and AS + R.

However, the AS + G treatment produced much greater absolute error on the first postrest trials than AS + R, and this contrast was significant with \( t (34) = 2.48, p < .05 \). This indicated that the gripping activities produced greater WUD than simply resting for the same interval of time and that the activity set for efficient positioning was disrupted by the adoption of the activity set for gripping. Further, since the gripping was done with the left hand, the problem of effector-specific effects in Exp. I was eliminated, and these results supported the view that the gripping activities had a centralized effect on the mechanisms underlying the positioning response.

These statistical tests were repeated with various alternative criteria which were (a) the difference between the absolute error on the first postrest trial and the mean absolute error on the last five trials of pre-rest practice and (b) the difference between the absolute error on the first postrest trial and the mean absolute error over the five trials just preceding the interpolated period in question; in all cases, the results were identical to those found using the first postrest trial, with the difference between Treatments REST and AS + R failing
The present experiments supported a number of predictions from the activity-set hypothesis. First, the difference (Exp. I) between the rest condition (Group REST) and the left-hand practice condition followed by a minimum interval (Group AS) replicated the original Nacson-Schmidt (1971) findings. Second, there was support for the prediction that increasing the interval from the end of the left-hand task to the right-hand task results in greater WUD, since this interval could allow S to readjust the relevant mechanisms to levels which are inappropriate for positioning. Although the pattern of elimination of the activity set over time is not known, it is clear that the rate of loss is quite rapid, since nearly all of the beneficial effects of the left-hand activity were lost by 25 sec. (Exp. II), and all appeared to be lost by 40 sec. (Exp. I).

Third, the present data support the prediction that causing S to adopt an activity set of a different class than that required for the criterion task should result in increased WUD, since the right-hand tapping activity in Exp. I and the left-hand gripping activities in Exp. II caused considerably greater WUD than the appropriate control conditions. It was apparent that effector-specific factors (e.g., fatigue) were causing some of the increased error with the tapping effects, but even when this problem was eliminated by having Ss grip with the left hand, the effect was still very large. In addition, the gripping activities of Exp. II involved considerably less time (only two attempts at maximum grip force) than the tapping activities, and a portion of the reduction of error from tapping to gripping may be due to this factor. In any case, it is clear that very little motor activity is required to disrupt the activity set completely.

While providing support for the activity-set hypothesis, the present findings cannot be accounted for by the set hypothesis. The set hypothesis states that WUD is due to factors specific to the criterion task. However, the present interpolated activities had neither apparatus, movement direction, nor part of the body in common with the criterion task, and the set hypothesis would predict that the activities in the interpolated interval would have no effect on WUD in the criterion task since they had no elements in common with it. Similarly, the increase in WUD from the gripping activities (Exp. II) cannot be explained by the set hypothesis since gripping had no elements in common with positioning.

The evidence from the present experiments and from Nacson and Schmidt (1971) support the notion that WUD is due to a loss of a generalized state of adjustment which underlies a small class of tasks with a common set of response requirements. Due to the fact that the set hypothesis cannot account for these findings, there is strong support for loss of this more generalized activity set as the cause of WUD.

REFERENCES


(Received February 10, 1971)