6-1981

A Comparison of the Central & Peripheral Theories of Work Decrement Through the Separation of Stimulus & Response Components in the Mental Imagery of a Motor Task

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A COMPARISON OF THE CENTRAL AND PERIPHERAL THEORIES OF WORK DECREMENT THROUGH THE SEPARATION OF STIMULUS AND RESPONSE COMPONENTS IN THE MENTAL IMAGERY OF A MOTOR TASK

A Thesis
Presented to the Faculty
Department of Psychology
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

BRUCE EVAN JENNINGS
June 1981

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Acknowledgements

Although words are often inadequate for the expression of sincere feelings, they're the only means of communication allowed by this medium.

I would like to express my thanks to the following people:

to my wife, Valerie, for her help, encouragement, and endurance;

to Dr. Daniel Roenker for the invaluable direction;

to Dr. Richard Miller and Dr. Sebastiano Fisicaro for their contributions to this effort;

to Mr. William Courtenay for his ideas and work on the modified rotor;

to Jane McDonald for typing this manuscript;

and to my parents for years of help.

Table of Contents

List of Illustrations

A COMPARISON OF THE CENTRAL AND PERIPHERAL THEORIES OF WORK DECREMENT THROUGH THE SEPARATION OF STIMULUS AND RESPONSE COMPONENTS IN THE MENTAL IMAGERY OF A MOTOR TASK

Bruce Evan Jennings June 1981 50 pages

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A total of 180 introductory psychology students from Western Kentucky University were tested with their left hands on the rotary pursuit apparatus. Practice conditions consisted of the following: imagery of the rotor's light movements (stimulus component), imagery of pursuit-type arm movements (response component), imagery of both light movements and arm movements, imagery of the integrated task, and a no practice control group. Nine-minute rest periods were given to half of the subjects in each of these conditions. In addition to providing a better understanding of the processes underlying mental imagery through the breakdown of its components, differences between the stimulus and the response groups would have allowed an assessment of the two theories of work decrement. Although the results did support the use of mental imagery as an aid to skill acquisition, conclusions could not be made regarding the two theories of work decrement. The failure to demonstrate work decrement raised doubt about the reliability of the results.

Literature Review

Learning is a frequently used term that may apply to numerous situations: classical conditioning, operant conditioning, verbal learning, or motor learning. Researchers in areas as diverse as biochemistry, education, neurophysiology, physical education, and psychology have sought to understand the learning aspects of human behavior.

Motor learning is a relatively new research area and is still undergoing major changes in emphasis. For example, during and shortly after World War II, investigations in the area emphasized the environmental conditions affecting performance. However, the focus has recently shifted to a concern with the physical and psychological processes underlying movements and physical skills (Stelmach, 1976).

Marteniuk (1976) has emphasized that perceptual-motor skills are cognitive in nature, being viewed as internally represented in the central nervous system. This results in an individual's ability to plan a movement and imagine its outcome without actually physically moving. Imagined movement, or mental practice, has been defined as thinking about a skill or watching someone else perform the skill in an attempt to improve subsequent physical performance (Marteniuk, 1976). Thinking about a skill is the type of mental practice with which this paper is concerned.

Investigations of mental practice have typically employed tasks normally used to assess the effects of physical practice. Furthermore, the effectiveness of mental imagery has been ascertained through comparisons with physical practice. The parallels between physical practice and mental practice are now discussed as a method of introducing the major concepts in the area of motor learning: skill acquisition, bilateral transfer, and work decrement. Following the presentation of these parallels, the central issue of this thesis will be examined, work decrement and the theories that have been proposed to explain it.

Physical Practice

Since they play a central role in the research of motor learning, it is important to examine three aspects of the physical practice of skills: skill acquisition, bilateral transfer, and work decrement. Early research in motor learning focused on the acquisition or improvement of skills through physical practice. Physical practice is a logical means of achieving skill acquisition. Experimental evidence also supports physical practice as a means of improving performance. Experiments involving the study of optimal practice conditions for archery shooting or the long-term retention of juggling skills were common in the early 1900's (Singer, 1968). More recently, Ammons (1947a) gave male college students eight 6-min trials on a rotary pursuit apparatus. The percentage of time on target increased with each trial. Additional studies supporting the use of physical practice for skill acquisition are too numerous to cite.

The second phenomenon that has been investigated with respect to physical practice is bilateral transfer. Bilateral transfer is a positive learning effect on one limb after physical rehersal of a skill with the contralateral limb. Ammons (1958) demonstrated bilateral transfer in a rotary pursuit study involving 192 female high school students. The subjects practiced with either the left hand or the right hand, rested 20-min , and then practiced with either the same or the other hand. With four experimental groups, all possible combinations of hand sequences were represented. The results of this experiment showed a significant amount of transfer of learning both from right hand to left hand and from left hand to right hand. This bilateral transfer of skill acquisition is well documented in the literature (e.g., Irion & Gustafson, 1952; Grice & Reynolds, 1952; Albright, Borrenson, & Marx, 1956; Walker, DeSoto, & Shelly, 1957; Ammons & Ammons, 1970; Singer & Milne, 1975).

The third phenomenon, work decrement, or a lowered quality of performance due to less-than-ideal conditions of practice and rest, has been investigated in studies of physical practice (Bell, 1942; Ammons, 1947b; Ammons & Ammons, 1970). Evidence for the existence of work decrement is collected in two ways. The first method is the single limb design. Practice trials are massed on one limb. After a rest period, performance is assessed using the same limb. The improved performance on the first post-rest trial relative to the last pre-rest trial is taken as evidence of the dissipation of a performance inhibiting factor known as work decrement.

The second way in which work decrement is demonstrated is through the use of a bilateral design. Subjects practice with one limb and are then given either a rest or a no-rest treatment. Finally, performance is measured with the contralateral limb. The difference in post-rest performance between rest and no-rest conditions is taken as evidence for the dissipation of work decrement.

Work decrement was demonstrated by Bell (1942) in a rotary pursuit investigation that involved 457 subjects. One control group consisted of 40 subjects. Ten experimental groups each consisted of 40 to 46 subjects. It was not specified which hand each subject used; however, the same hand was used on every trial. This represents a single limb design. Twenty 1-min trials, alternated with 1-min rest intervals, were used. Groups B, C, D, E, and F received a 10-min, 1-hour, 6-hour, 24-hour, and 30-hour rest, respectively, after the 5th trial. Groups G, H, I, J, and K received a 10-min, 1-hour, 6-hour, 24-hour, and 30-hour rest, respectively, after the 15th trial. A reference curve was derived from the combination of the control group's learning curve with the average performance of groups G, H, I, J, and K through the first 15 trials. In comparison to this reference curve, all groups with early rest (B, C, D, E, and F) showed improved performance on trial 6. Of the late rest groups, only group G showed improved performance on trial 16. However, groups H, J, and K were also above the reference curve by trial 17. This study demonstrates the importance of the length and onset of rest intervals in the acquisition and practice of a motor skill. As Ammons (1947b) stated, the rest period allows for dissipation of work decrement (a negative factor which inhibits performance). Therefore, improved performance will follow an adequate rest period. Decrement-dissipating rest can occur in one long interval between practice and performance trials or in lengthened intertrial intervals. This effect, known as reminiscence, is well-documented in the literature (e.g., Kimble & Horenstein, 1948; Ammons, 1950; Koonce, Chambliss, & Irion, 1964).

Kimble (1952) reported an experiment that demonstrated bilateral transfer of work decrement. Thirty volunteers performed 30 rotary pursuit trials with the non-preferred hand. Fifteen of the subjects rested for 5 min before performing 30 trials with the preferred hand. The remaining 15 subjects received no rest before the final 30 trials. The group that received the rest performed at a significantly higher level on the final 15 trials. This bilateral transfer of work decrement is also a well-documented phenomenon (e.g., Ammons & Ammons, 1951; Grice & Reynolds, 1952; Irion & Gustafson, 1952).

In summarizing this section on physical practice, several points must be emphasized. First, physical practice with one limb leads to improved performance with the same limb. Second, two results are obtained through the use of a bilateral transfer design. The experimental group's performance with the contralateral limb is better than a control group's performance regardless of whether or not practice is followed by a rest period (i.e., bilateral transfer of skill occurs). The second result obtained is that transfer following a rest is better than transfer without a rest (i.e., the dissipation of work decrement during a rest results in the highest level of performance). Third, work decrement can also be demonstrated in a single limb design by comparing performance following a rest with performance uninterrupted by a rest period.

Mental Practice

The author has already stated that this thesis is concerned with the type of mental practice that involves thinking about a skill in an attempt to improve subsequent physical performance. Studies of the effects of mental practice in human motor learning have produced results that parallel the effects of physical practice for all three phenomena just described: skill acquisition, bilateral transfer, and work decrement.

Rawlings, Rawlings, Chen, and Yilk (1972) provided experimental evidence that supports mental practice as an aid to skill acquisition. In this study, 24 female undergraduates were randomly assigned to three groups. On the first day, all subjects practiced pursuit rotor tracking with the preferred hand for 25 30-sec trials. For each of the next eight days, Group 1 physically practiced tracking for 25 trials; Group 2 visualized the rotor and the movement required in tracking and mentally practiced the task; Group 3, the control group, was given 25 trials of color naming. On the 10th day, all subjects were tested for 25 trials, again with the preferred hand. The performance of both experimental groups was significantly better than the control group's performance and they did not differ from each other. Mental practice was as effective as physical rehersal in the acquisition of rotary pursuit skill.

Oxendine (1969) conducted three separate experiments in an attempt to determine the effects of different schedules of mental and physical practice. In the first experiment, 80 high school students were assigned to one of four practice conditions. During a 7-day training period, Group 1 physically practiced the rotary pursuit task (56 physical practice trials). The practice of Group 2 was 75% physical and 25% mental with one mental practice trial followed by three physical practice trials. Group 3 practiced 50% physically and 50% mentally with one mental trial followed by one physical trial. Group 4 practiced physically for only 25% of its trials with three mental trials followed by one physical trial. Assessment of skill acquisition was made on the first day after the final day of practice. There were no significant differences among the first three groups. However, Groups 1 and 2 performed significantly better than Group 4. Group 3 narrowly missed achieving significant improvement over Group 4. Second, Oxendine used the same experimental design with a soccer kick task. Approximately equal amounts of improvement in performance were achieved by all groups. Third, none of the groups showed significant improvement when a modified basketball jump shot was used in the same experimental design. Oxendine concluded from these experiments that devoting 50% of practice time to physical practice and 50% to mental practice can be as effective as 100% physical practice.

In summary, both Rawlings et.al. (1972) and Oxendine (1969) support mental practice as an effective means of skill acquisition.

Many other studies provide additional support; Richardson (1967) and Corbin (1972) extensively review these studies.

To this author's knowledge, only two investigations have been made of bilateral transfer as a function of mental practice. Arnold (1946) described a study by Beattie in which subjects improved aim with both arms after imagining a dart-throwing task with only one arm. Kohl and Roenker (1980) reported three experiments which demonstrated bilateral transfer in a mentally-practiced rotary pursuit task. In the first of these experiments, subjects were assigned to a mental imagery, physical practice, or control group. They then alternated 25 30-sec rehersal trials with 25 30-sec rest intervals. Subjects in both mental imagery and physical practice groups rehearsed with their right hands and were required to physically perform with their left hands (i.e., a bilateral transfer design). A post-hoc Newman-Keuls test indicated no significant difference between mental imagery and physical practice groups, but showed that both groups differed significantly from the control group. Although the remaining two experiments reported by Kohl and Roenker demonstrated bilateral transfer of skill acquisition, they also demonstrated work decrement in a bilateral design. These two experiments will be discussed below with respect to work decrement.

It has already been stated in reference to physical practice that work decrement may be demonstrated in two ways: through a single limb design or through a bilateral design. This is also true regarding the demonstration of work decrement with mental practice.

Rawlings and Rawlings (1974) gave 47 female college students concentrated physical practice (50 sec of work alternated with 10 sec of rest) for 5 min. Ten min of rest was followed by 5 min of post-rest practice with the same limb (i.e., a single limb design). Twelve control subjects performed an irrelevant task during the rest period while 35 subjects mentally rehearsed the rotary pursuit task. Imagery subjects exhibited more work decrement in the post-rest performance, indicating that mental rehearsal of the task during the rest period prevented the dissipation of work decrement.

To this author's knowledge, only two studies have demonstrated bilateral transfer of work decrement with a mentally-imaged task. The second experiment by Kohl and Roenker (1980) replicated the evidence of bilateral transfer of skill in the mentally-imaged task and attempted to assess the relative effectiveness of mental imagery and physical practice in bilateral transfer by subjecting the experimental groups to conditions of fewer practice trials and increased duration of interpolated rest than the groups of the first experiment. It was suggested that these changes would minimize the build-up and transfer of work decrement in the physical practice group. Because bilateral transfer of work decrement had never been demonstrated in mental practice, Kohl and Roenker expected the minimization of work decrement in physical practice to allow a discrimination between the relative effectiveness of physical and mental practice. The results of this experiment again failed to demonstrate a difference between mental imagery and physical practice groups. However, both groups again exhibited performance superior to that of the control group. It was suggested that both groups accumulated and recovered from work decrement.

The final experiment reported by Kohl and Roenker demonstrated that mental imagery does produce a bilateral transfer of work decrement as well as bilateral transfer of skill. A total of 108 right-handed males were randomly assigned to six groups. The mental-imagery rest group received a right-handed demonstration of the rotary pursuit task, nine 30-sec right-handed imagery trials, a 9-min rest, and nine 30-sec left-handed physical performance trials. The mental-imagery no-rest group received an 8-sec rest instead of the 9-min rest. Physical rehearsal procedures were the same as the imagery procedures with the substitution of right-handed physical practice for the mental imagery. Control groups verbalized multiplication tables before performing left-handed rotary pursuit trials. The superiority of the mental-imagery rest group over the mental-imagery no-rest group demonstrated the production of work decrement by mental imagery. In summary, the experiments of Kohl and Roenker showed that mental or physical practice with one limb results in positive transfer to the contralateral limb. In addition, the bilateral transfer of work decrement was demonstrated under both mental practice and physical practice conditions.

White (1981) required subjects to mentally practice right-handed rotary pursuit tracking at either 30, 45, or 60 rpm. After a rest period, subjects physically performed the rotary pursuit task with the left hand (i.e., a bilateral design) at

45 rpm. Half of the subjects rested following imagery practice and half did not. Comparisons with appropriate no-rest groups replicated Kohl and Roenker's evidence of bilateral transfer of work decrement. In addition, practice at 30 or 60 rpm was demonstrated to improve skills at 45 rpm (i.e., intertask transfer of skill).

In summary of this section on mental practice, several points emphasized in the discussion of physical practice are also of importance in mental imagery. First, practice (either physical or mental) with one limb leads to improved performance with the same limb. Second, two results are obtained through the use of a bilateral transfer design with either physical practice or mental practice. Practice with one limb leads to performance with the contralateral limb which is better than a control group's performance regardless of the amount of rest prior to transfer, and transfer following a rest is better than transfer without a rest (i.e., a demonstration of the dissipation of work decrement). Finally, work decrement can be demonstrated in single limb designs using mental imagery, just as it can be demonstrated with physical practice.

It has been demonstrated that physical practice and mental practice are are approximately equivalent in reference to three important phenomena. These three phenomena are skill acquisition, bilateral transfer, and the production of work decrement (with either a single limb or a bilateral design). These parallels show that mental practice is both a valid method of practicing a motor skill and a valid approach to the investigation of work decrement. If, however, the theories of work decrement are to be tested through the use of mental practice, it is first necessary to discuss those theories of work decrement.

Theories of Work Decrement

One of the major disputes in the motor learning literature is whether work decrement is central or peripheral in nature. The most commonly accepted explanation of work decrement is based on Hull's notion of inhibition. His ideas have been used to explain work decrement in both single limb and bilateral designs.

According to Hull (1943), "each response evocation produces a . . . condition which constitutes a need for rest . . . this condition has the capacity directly to inhibit the power of S to evoke R" (p. 391). This is called reactive inhibition. The accumulation of reactive inhibition was presented by Hull as the cause of experimental extinction. Spontaneous recovery was theorized to be the progressive removal of reactive inhibition from the tissues.

The presence of reactive inhibition constitutes a need, the need to stop working. The cessation of work initiates the need-reduction process, the reduction of reactive inhibition. "Stimuli closely associated with the cessation of the response become conditioned to the (reactive) inhibition associated with the evocation of that response" (Hull, 1943, p. 300). As these stimuli become associated with reactive inhibition, they too will serve to inhibit the response. The inclusion of these inhibitory stimuli in a stimulus compound produces conditioned inhibition. Thus, the generation of conditioned inhibition is dependent upon the presence of reactive inhibition. Furthermore, the total inhibition in the extinction of a response must be partially reactive inhibition and partially conditioned inhibition.

The relationship of Hull's terms to work decrement terminology is described in a review of rotary pursuit studies by Ammons and Ammons (1970). The reported studies utilized the work-rest-work cycle as the basic unit of skills practice. Before examining the concepts which parallel Hull's reactive inhibition and conditioned inhibition, it is necessary to examine a third concept. This is the concept of warmup decrement. Warmup decrement is the initial decrement in post-rest performance due to the necessity for the subject to warm up after rest. It is the difference between the subject's actual level of performance and the estimate of warm-up-free performance that is based upon extrapolation of the post-rest performance curve obtained by graphing performance levels.

Ammons and Ammons define permanent work decrement as the amount which the estimated initial level of post-rest performance, corrected for warmup decrement, falls below performance under ideal distribution of practice and rest. Permanent work decrement is related to Hull's conditioned inhibition. It is reportedly difficult to find and, when found, is very small in amount (Ammons & Ammons, 1970).

Temporary work decrement is an estimate of the improvement in performance that would occur at any point after rest. This estimate is based on extrapolation of learning curves and correction for warmup decrement. Because of the difficulty in isolating permanent work decrement, temporary work decrement is the phenomenon usually referred to in motor learning studies as simply "work decrement." Ammons (1947a) states that temporary work decrement is similar to reactive inhibition. This similarity is in the progressive reduction of either, that may be observed with the passage of time after work has ended. Temporary work decrement appears during performance of many motor skills, transfers from limb to limb (bilateral transfer), and transfers across closely related skills (intertask transfer).

This explanation of work decrement is peripheral in nature. That is, the mechanism which produces work decrement is largely localized in the muscle groups required to perform the task. This effector based model has been used to explain the work decrement phenomenon observed in physical practice conditions (e.g., Hsu & Payne, 1979). In addition, it has been generalized to explain work decrement effects obtained with mental imagery in single limb studies. The effector based (or peripheral) argument is based on findings that mental practice of a motor skill activates subliminal neuromuscular units localized in specific muscles that would subsequently perform the imaged skill (Jacobson, 1931, 1932). The relative contribution of the central nervous system is minimal, according to advocates of the peripheral theory.

In contrast to the peripheral theory of work decrement, a more central explanation has been offered. This central theory of work decrement emphasizes the role of the central nervous system, the incoming sensory messages, and the outgoing commands to the muscle groups. Ammons and Ammons (1970) have described the central theory. They state that work decrement "can be assumed to be loading of inhibition on perceptual patterns as a function of the time they are present" (p. 220). While this central theory provides little detail as to the basic mechanisms, it represents a shift in emphasis concerning the core mechanism involved in the production of work decrement.

Both of these theories (central and peripheral) have been applied to the production of work decrement in both physical practice and mental practice. However, the central theory was formulated as a result of work in mental practice. The peripheral theory was based on studies of physical practice and later extended to mental practice.

Evidence of bilateral transfer with mental imagery (Kohl & Roenker, 1980) presents a problem for the peripheral theory in that neuromuscular activation occurs only in the imaged limb (Jacobson, 1932). Therefore, it cannot explain the facilitation that occurs with transfer to another limb.

Two additional studies should be examined in reference to the central-peripheral debate. The first of these studies (Adams, 1955) tested 356 basic airmen trainees on the pursuit rotor. Trial length was 1 min with intertrial rests of 10 sec. Each group had two sets of 10 trials with the preferred hand. Between these sets of trials, one of five conditions was interpolated: 1) while watching a demonstrator practice the rotary pursuit, each subject was required to press a button with the non-preferred hand when the demonstrator contacted the target and release the button whenever contact was lost (<u>this button</u>

pushing activity was used to force attention to the rotary pursuit task without requiring subjects to make a pursuit-type response); 2) the response required in the first condition was followed by a 10-min rest; 3) button pushing in response to a random auditory signal; 4) an unfilled seated rest; and 5) a 14-min and 50-sec rest taken in the testing room while standing in front of the pursuit rotor. In the final set of trials, Groups 2 and 4 performed at the highest level without a significant difference between them. Group 1 performed at a significantly lower level. Although Groups 3 and 5 fell below Groups 2 and 4, there was not a significant difference to suggest that these conditions produced work decrement. These results indicated that standing or button pushing in response to an auditory signal (conditions 5 and 3) did not produce work decrement. However, the visual pursuit of the target and the act of distinguishing the discrepancy between the stylus tip and the target (conditions 1 and 2) were sources of work decrement. In addition, the 10-min rest taken after this activity (condition 2) was sufficient for the dissipation of decrement. Adams' conclusion was that the act of button pushing was not sufficient for the production of work decrement. A cognitive component (i.e., attention to the rotary pursuit task) was necessary.

Rosenquist (1965) attempted to replicate Adams' results and test them for generality. Rosenquist required 198 right-handed females to practice the rotary pursuit for 5 continuous minutes with the right hand. Subsequent activities were various combinations of 0-, 3-, 6-, or 9-min periods of watching and right-handed button-pushing (similar to the Adams task) with 0-, 3-, 6-, 9-, or 18-min periods of rest. Finally, all subjects completed a 5-min, left-handed rotary pursuit trial. Rosenquist confirmed Adams' findings that work decrement was produced by the visual response component of the rotary pursuit task. In addition, Rosenquist found that decrement dissipates at two rates: slowly during active watching and readily during rest.

In summary, the results of these experiments suggested two conclusions in support of the central theory of work decrement. First, the visual input is an important component of rotary pursuit skill. Second, this visual input alone can produce work decrement.

This body of literature presents data that are in opposition to the peripheral theory of work decrement and in support of the central theory. Therefore, the purpose of this experiment was twofold. First, the experiment provided another test of the central and peripheral theories of work decrement. Second, the experiment separated mental imagery into its constituent parts in an attempt to better understand the underlying processes.

Testing the Theories

The primary concern of this thesis was to produce evidence in support of either the central or peripheral theory of work decrement through the mental imagery of a rotary pursuit task. Use of the rotary pursuit apparatus was desirable for two reasons: previous documentation of its use in producing work decrement and the ease with which it produces quantified scores.

There were three reasons for using mental imagery instead of physical practice. First, as mental and physical practice have been shown to be approximately equivalent in the production of work decrement, mental practice is one valid way of testing the central and peripheral theories. Second, mental practice in itself is an interesting topic of study. It offers several advantages over physical practice. For example, a task can be mentally practiced when one does not have access to the resources necessary for physical practice. Similarly, it is possible to mentally practice one's tennis serve while sitting through an uninteresting lecture. One can also practice a skill through mental imagery when injury makes physical practice an impossibility. Third, mental imagery is an easy way to break down the components of a task. The importance of separating the components of a task is considered next.

In order to produce evidence in support of either the central of peripheral theory, it was necessary to fulfill two requirements. First, a group of subjects were required to practice the movement of a specified limb so that neuromuscular activation would be produced. The effect of that activation was then assessed in order to determine the validity of the peripheral theory. Second, a group of subjects practiced in a manner that eliminated any movement and concomitant neuromuscular activation. Improvement in the performance of this group would have supported the central theory.

In rotary pursuit experiments, subjects have typically observed the experimenter perform the task and have then been asked to imagine themselves performing. However, in this experiment, one group of subjects imagined the movement of a photoelectric rotor's light (i.e., the stimulus component). Another group of subjects was required to image the arm movements (i.e., the response component) used in performing the task.

Each group then performed the rotary pursuit task and their performance levels were tested for significant differences. Because the mental practice used by the stimulus group involved only the perception and imagery of moving light and not actual body movements or even the imagery of such movements, it can be inferred that no neuromuscular activity occured. Therefore, a higher level of performance by the stimulus group would have supported the central theory of work decrement. Conversely, as the response condition specifically required the imagery of physical movement, with its concomitant neuromuscular activity (Jacobson, 1931), a higher level of performance by the response group would have supported the peripheral theory of work decrement. A rest and no-rest variation of each treatment condition was used to determine the effectiveness of each condition through the assessment of the production of work decrement.

Method

Subjects

A total of 180 right-handed students drawn from introductory psychology classes at Western Kentucky University was randomly assigned to one of 10 groups with the restriction that each group consist of 18 subjects. During recruitment, right hand dominance and naivete to the pursuit rotor were established. The subject's own assessment was the criterion for dominance. All subjects practiced and were tested individually.

Design

The experiment was a 5 x 2 x 9 mixed factorial design with repeated measures on the last variable. The first variable represented treatment conditions. The conditions were as follows: 1) Stimulus, each subject observed and imaged the revolving light on a pursuit rotor; 2) Response, each subject felt and imaged the arm movements produced by holding a stylus-like handle on a revolving modified pursuit rotor; 3) Stimulus-response, each subject saw the revolving light, felt the arm movements, and imaged both; 4) Observation, each subject observed the experimenter perform the rotary pursuit task and then imagined himself performing; and 5) Control, each subject read magazines for the time equivalent to the practice trials.

The second variable represented the amount of rest between practice and test sessions. The Rest groups received a 9-min rest between practice trials and performance trials while the No-rest groups received only a 30-sec rest. Finally, the third variable was the repeated performance score. Each subject had one score on each of nine 30-sec performance trials.

Apparatus

Equipment included a Lafayette photoelectric pursuit rotor (model number 30013), a BRS-Foringer timer (model number TI-906), a Lafayette timer (model number 54025), and a modified Lafayette electric-contact rotary pursuit apparatus which was used to present imaging stimuli to the subjects. This modified rotor was covered by a wooden box so that its dimensions were identical to those of the photoelectric rotor. The top of the modified rotor was painted black to further increase resemblance between the two instruments. A circular portion of this wooden cover was attached to the rotating portion of the rotor; these two pieces rotated in unison. The rotating portion of the wooden cover had a square piece of translucent plastic (the same size as the photoelectric rotor's light) that could be lighted from below. This square of plastic rotated on a circular path with a diameter of 29.71 cm, the same as the diameter of the light's path on the photoelectric rotor. A wooden stylus-shaped handle was attachable to the modified rotor at the square of plastic.

All stimulus presentations and practice trials involved the right hand. Subjects were tested on the photoelectric rotor at 45 rpm with the left hand. The rotor was connected to a BRS-Foringer timer which programmed the rotary pursuit for alternating 30-sec periods of performance with 30-sec rest intervals. A Lafayette timer recorded the subject's total time on target for each trial. The pursuit rotors were checked for accuracy between subjects. A tape with ticks recorded at 45 ticks per min was used to provide a time reference for the subjects' images.

Procedure

Upon entering the experimental room, each subject was randomly assigned to one of 10 groups: 1) Stimulus Rest, 2) Response Rest, 3) Stimulus-response Rest, 4) Observation Rest, 5) Control Rest, 6) Stimulus No-rest, 7) Response No-Rest, 8) Stimulus-response No-Rest, 9) Observation No-rest, and 10) Control No-rest. Each experimental group experienced a 1-min demonstration of the appropriate image. Practice conditions for each group consisted of 18 30-sec imagery trials separated by 30-sec rest intervals. Performance appraisal for each group consisted of nine 30-sec trials separated by 30-sec rest intervals. All rest groups received a 9-min rest period between the practice and performance conditions. Subjects read magazines during these rest periods. All no-rest groups received only the regular 30-sec rest period between the last practice trial and the first performance trial.

Conditions

Stimulus Rest (SR). Each subject observed the rotating light on the photoelectric rotor for 1 min while listening to the 45 ticks-per-min tape. He was then instructed to close his eyes and imagine the movement of the target light. The tape of ticks was played during imagery trials to give a stable time reference to each image. Each subject was instructed to have his imaged light reach a predesignated point in its path in correspondence with the tick. Subjects were required to image the light for 18 trials. They then received a 9-min rest period in which to read magazines. The rest period was followed by nine performance trials on the photoelectric rotor.

Response Rest (RR). Each subject was blindfolded. A wooden dowel rod (with a diameter of 1.59 cm) was placed in his hand and moved in random directions by the experimenter. This was to prepare subjects for following the pull of the modified rotor rather than resisting it. The subject's hand was then placed on the stylus-like handle of the modified rotor which guided his arm for a 1-min period. Each subject was asked to image the feelings of the movement for 18 trials. The recording of ticks was used to provide a time reference as in the Stimulus condition. Subjects then received a 9-min rest. Nine performance trials followed the rest.

Stimulus-response Rest (SRR). The wooden dowel rod was used to prepare the subject as in the Response condition. Each subject then allowed the modified rotor to guide his arm around for 1 min while simultaneously observing the moving light. The subject was asked to image both components of the task for 18 trials with the recorded ticks providing time reference. He then received a 9-min rest period followed by nine performance trials.

Observation Rest (OR). Each subject observed the experimenter perform the rotary pursuit task for 1 min. He was then asked to imagine himself performing the task for the regular practice trials. The subject's images were again paced by the tape recording. A 9-min rest and nine performance trials followed.

Control Rest (CR). Each subject read magazines for the time equivalent to the practice trials. He continued reading through the 9-min rest period. The rotary pursuit apparatus was not visible at this time. Subjects then observed the experimenter perform a 1-min trial on the pursuit rotor at a target speed of 45 rpm. This was immediately followed by the performance trials.

The No-rest groups were as follows: Stimulus No-rest (SNR), Response No-rest (RNR), Stimulus-response No-rest (SRNR), Observation No-rest (ONR), and Control No-rest (CNR). They experienced the same procedures as the rest groups with one exception. That difference was a 30-sec rest interval after the 18th imagery trial instead of a 9-min rest. The time that the Control No-rest subjects were required to read magazines was reduced appropriately. The instructions that were read to subjects in each group may be found in the Appendix.

Results

Each subject in the experiment received a score for each of the nine performance trials. Because each score was the total time on target for each of the 30-sec trials, a subject's score on one trial could have ranged from 0.00 to 30.00 sec (time was measured to the hundredth of a sec).

An analysis of variance performed on these data (see Table 1) revealed a significant difference among treatments, $F(9,170)=2.07$, $p < .05$. Although there was a significant increase in performance across trials, $F(8,1360)=167.70$, $p < .05$, there was not a significant interaction between treatment and trials, $F(72,1360)=1.22$, $p > .05$. Since there was not a significant interaction between treatment and trials, the data were collapsed across trials and are presented graphically in Figure 1. In addition, actual mean values and standard deviations are presented in Table 2.

Table 1

ANOVA Summary Table and
F Values for Orthogonal Contrasts
of Treatment Effects

Orthogonal Contrasts

1. CR vs CNR
2. CR,CNR vs SR,RR,SRR,OR,SNR,RNR,SRNR,ONR
3. SR vs SNR
4. RR vs RNR
5. OR vs ONR
6. SRR vs SRNR
7. SR,SNR vs RR,RNR
8. OR,ONR vs SRR,SRNR
9. SR,SNR,RR,RNR vs OR,ONR,SRR,SRNR

Analysis of Variance
Summary Table

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Tail Probability
Total	17493.58	1619	10.81		
Treatment	1169.07	(9)	129.90	2.07	<.05
Contrast 1	71.31	1	71.31	1.14	NS
2	709.37	1	709.37	11.30	<.05
3	89.20	1	89.20	1.42	NS
4	27.27	1	27.27	<1	NS
5	21.26	1	21.26	<1	NS
6	.05	1	.05	<1	NS
7	89.63	1	89.63	1.43	NS
8	12.22	1	12.22	<1	NS
9	150.74	1	150.74	2.40	NS
Error	10669.01	170	62.76		
Trial	2719.77	8	339.97	167.70	<.05
Trt by Trial	178.58	72	2.48	1.22	NS
Error	2757.15	1360	2.03		

Figure 1

Time on Target as a
Function of Treatment and Rest

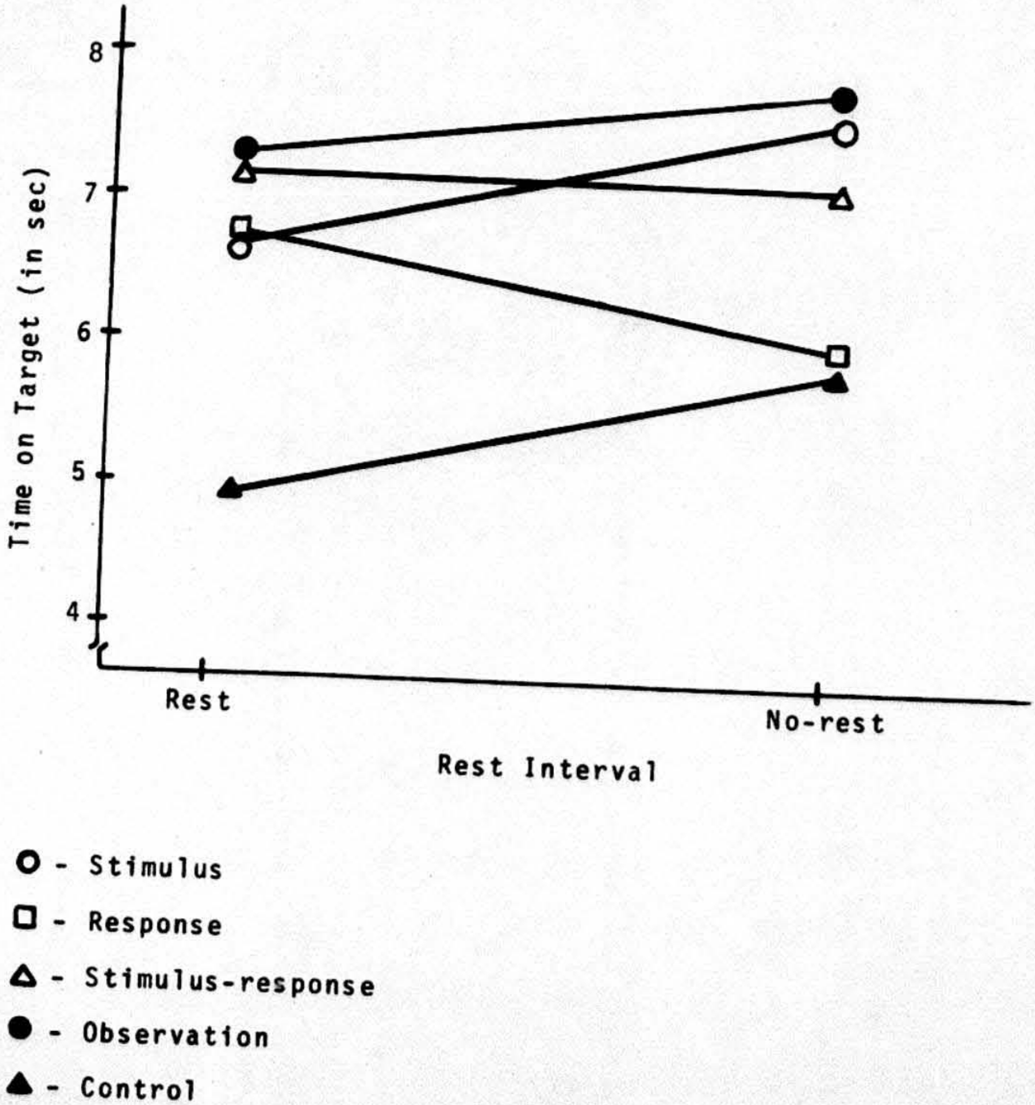

Table 2

Cell Means (M) and Standard Deviations (SD)

	Rest	No-rest
Stimulus	M = 6.52 SD = 3.14	M = 7.57 SD = 3.15
Response	M = 6.59 SD = 2.72	M = 6.01 SD = 3.01
Stimulus-response	M = 7.20 SD = 3.24	M = 7.23 SD = 2.85
Observation	M = 7.23 SD = 2.76	M = 7.75 SD = 3.46
Control	M = 4.89 SD = 2.37	M = 5.83 SD = 2.77

The overall treatment effect was partitioned into nine orthogonal components (see Table 1). The first comparison tested the difference between the two control groups (rest and no-rest). As expected, these groups did not statistically differ. The second comparison tested the eight experimental groups (Stimulus Rest, Response Rest, Stimulus-response Rest, Observation Rest, Stimulus No-rest, Response No-rest, Stimulus-response No-rest, and Observation No-rest) against the two control groups. These eight groups when pooled were superior to the control groups. This comparison supports previous findings that mental imagery can be used to improve skills.

The third comparison tested the Stimulus Rest group against the Stimulus No-rest group in an attempt to determine whether work decrement was produced by the stimulus treatment. The dissipation of work decrement would have produced a higher level of performance in the Stimulus Rest group. As is evident from Table 1, these groups did not statistically differ. The next three comparisons tested for the production of work decrement in the remaining three treatments. Response Rest was tested against Response No-rest. Observation Rest was tested against Observation No-rest. Stimulus-response Rest was tested against Stimulus-response No-rest. The failure of all of these comparisons to reach statistical significance suggests that work decrement may not have been produced by any of the treatments.

The seventh comparison tested the stimulus groups against the response groups. This comparison was designed to test the central theory of work decrement (through the stimulus groups) against the peripheral theory (through the response groups). The central theory predicts that the stimulus groups will perform better than the response groups, and the peripheral theory predicts that the response groups will perform better than the stimulus groups. As the comparison did not reveal a significant difference, no conclusion regarding the two theories can be made. As the third and fourth comparisons failed to demonstrate the production of work decrement, and these comparisons have been known to produce work decrement before (i.e., Kohl & Roenker, 1980), any conclusions about the theories of work decrement would be suspect.

The eighth comparison tested the observation groups against the stimulus-response groups to determine whether different combinations of task components would produce different results. As the pooled groups did not differ, no difference between the treatments is indicated.

The final comparison tested the stimulus only and response only groups pooled against the observation and stimulus-response groups pooled. This test was intended to determine whether imagery of a combination of task components would improve performance more than the imagery of a single component. The failure of the comparison to reach significance does not support this hypothesis.

In summary, these results indicated a significant improvement across trials. There was a significant treatment effect; all imagery groups pooled performed at a higher level than the control groups. However, orthogonal contrasts failed to support differences that would indicate the production of work decrement. As work decrement was not clearly demonstrated, comparison of the theories of work decrement would be suspect.

Discussion

The only significant difference indicated in Table 1 (control groups vs. all other groups) supported other findings (Rawlings, Rawlings, Chen, & Yilk, 1972; Kohl & Roenker, 1980) that mental imagery does lead to skill acquisition. However, the failure of Comparisons 3 and 4 (Stimulus Rest vs. Stimulus No-rest and Response Rest vs. Response No-rest) to reach significance made it difficult to draw conclusions regarding the validity of either the central or peripheral theory of work decrement. Each rest group should have performed better than the corresponding no-rest group due to the dissipation of work decrement. Previous studies using essentially the same procedures (Kohl & Roenker, 1980; White, 1981) have produced work decrement. This failure to replicate evidence of work decrement raised doubt as to the reliability of these results.

There are two possible explanations of the failure of this experiment to produce work decrement. The first is that the 18 imagery trials may have exceeded the attentional capacity of the subjects. This could have resulted in boredom and diminished effort. Diminished effort in the later trials would have allowed the dissipation of work decrement just as in a rest period. It should be noted that boredom would also have interfered with the positive effect of skill acquisition.

However, there is no reason to expect this to affect the groups differentially. Second, the 30-sec intertrial intervals may have been long enough to allow some dissipation of work decrement.

Although it is unlikely that valid conclusions regarding work decrement could be based on an experiment that failed to produce evidence of work decrement, it is possible to speculate about the relative importance of the components of the task based on the relative standings of the groups. The failure of the experimental treatments to produce different levels of performance is highlighted by the failure of the pooled stimulus only and response only groups to differ from the pooled stimulus-response and observation groups (comparison 9). This may indicate that the imagery of only one component is as effective as the imagery of both components or even of the integrated task. This raises several questions. Is the imagery of only one component sufficient for the improvement of skill? Does the imagery of one component trigger imagery of the other components of the task and how does this occur when subjects are naive to the task? And finally, was the time reference the critical element of skill acquisition in this task? It has already been stated that all imagery groups when pooled performed better than the control groups; there were no significant differences among any of these imagery groups. One element that all imagery treatments shared was the use of the 45 ticks-per-min tape. Perhaps the speed of the rotary pursuit apparatus was learned by all groups, even those who were not told in advance how to use the apparatus.

It is suggested that this experiment would have been more successful in producing work decrement with 9 to 12 30-sec imagery trials and an 8-sec intertrial interval instead of the 18 30-sec trials with 30-sec intervals. In addition, physical practice of the two components could be added for comparison. One group could be added to physically follow the stylus of the modified rotor for nine trials (response component). Another group could watch the rotor's light revolve instead of imaging (stimulus component). The groups could then perform the rotary pursuit task and be compared to a control group that received no practice. Comparison of the performance of those physical practice conditions would allow a better understanding of how practice of the two components affects performance. Again, the central theory would predict better performance by the group practicing the stimulus component, and the peripheral theory would predict better performance by the response group.

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Appendix

Instructions to Subjects

The complete set of instructions used in this experiment consists of eight sections. These sections (identified by Roman numerals) were combined in the following orders for presentation to each group.

Groups	Instruction Sections
Stimulus Rest	I, VI, VII, VIII
Response Rest	II, VI, VII, VIII
Stimulus-response Rest	III, VI, VII, VIII
Observation Rest	IV, VI, VII, VIII
Control Rest	V
Stimulus No-rest	I, VI, VIII
Response No-rest	II, VI, VIII
Stimulus-response No-rest	III, VI, VIII
Observation No-rest	IV, VI, VIII
Control No-rest	V

The various sections used to construct the instructions follow. Words in parentheses served as instructions to the experimenter. All other words were read to the subjects.

Section 1

Please pay close attention; it is essential that you have a clear understanding of what is about to be said. In order to insure accurate and valid testing, it is requested that you not discuss these proceedings with other students.

Observe the rotating light and listen to the ticks on this tape (turn on photoelectric rotor and tape of ticks). Note that the light is at approximately the same part of the circle whenever you hear the tick (allow 1 min of observation). Do you have any questions about the relationship between the speed of the target and the ticks on the tape?

Now sit on this stool. You are now to mentally image the rotation of the target light. Mental rehersal refers to imagining a task without making any observable movements. Your task is to imagine the rotation of the light. You must close your eyes. Conceptualize and create a mental image of the rotating light. The rotation should be a continuous and fluid movement. You will have 18 30-sec imagery trials. Between trials, you will have 30 seconds in which to rest.

While you are imaging, you will hear a series of ticks. These ticks will help you imagine the speed at which the target is rotating. As you remember from the demonstration, each tick corresponds to one revolution of the target. It is very important for you to carry out the instructions to the best of your ability. Can you tell me in your own words what I want you to do?

When you hear the ticking start, begin mentally imagining the target. When the ticking stops, rest. When the ticking resumes, immediately begin imagining target rotation again. Create an image for the entire trial that corresponds with the ticks.

Section II

Please pay close attention; it is essential that you have a clear understanding of what is about to be said. In order to insure accurate and valid testing, it is requested that you not discuss these proceedings with other students.

You will need to wear this blindfold for the next few minutes (put blindfold in place and guide subject to the modified rotor). Now hold onto this stick. Relax your arm and let me use the stick to guide your arm (move dowel rod in random directions—assure relaxation—may have to encourage by saying "relax your arm a little more—let me guide its movements").

Good. Now keep the blindfold on and place your hand on this wooden stick (help subject place hand on modified rotor stylus). Let this stick guide your arm movements (turn on modified rotor—assure fluid movement—encourage relaxation—turn tape on). Note that your arm is in approximately the same position whenever you hear the tick (allow a 1-min demonstration). Do you have any questions about the relationship between the speed of your arm movements and the ticks on the tape?

(Move partitions so that subject can't see either rotor, remove his blindfold). Now sit on this stool. You are now to mentally image the movements you just made. Mental rehearsal refers to imagining a task without making any observable movements. Your task is to imagine the bodily movements you have just made. You must close your eyes. Conceptualize and create a mental image of those movements. The movements should be continuous and fluid. You will have 18 30-sec imagery trials. Between trials, you will have 30 seconds to rest.

While you are imaging, you will hear a series of ticks. These ticks will help you imagine the speed at which the movements were made. As you remember from the demonstration, at each tick your arm was in approximately the same position. It is very important for you to carry out the instructions to the best of your ability. Can you tell me in your own words what I want you to do?

When you hear the ticking start, begin mentally imagining your movements. When the ticking stops, rest. When the ticking resumes, immediately begin imagining again. Create an image for the entire trial that corresponds with the ticks.

Section III

Please pay close attention; it is essential that you have a clear understanding of what is about to be said. In order to insure accurate and valid testing, it is requested that you not discuss these proceedings with other students.

You will need to wear this blindfold for the next few minutes (put blindfold in place—move to modified rotor). Now hold onto this wooden stick. Relax your arm and let me use the stick to guide your arm (move dowel rod in random directions—assure relaxation—may have to encourage by saying "relax your arm a little more—let me guide its movements").

Good (remove blindfold). Now place your hand on this wooden stick (place subject's hand on modified rotor stylus). Let this stick guide your arm movements and observe the rotating target light (turn on rotor and light—assure fluid movement—encourage relaxation—turn tape on). Listen to the ticks on this tape. Note that the light and your arm are in approximately the same position whenever you hear the tick (allow a 1-min demonstration). Do you have any questions about the relationship between the speed of the light and arm movements and the ticks on the tape?

Now sit on this stool. You are now to mentally image the rotating light and the body movements you just made. Mental rehearsal refers to imagining a task without making any observable movements. Your task is to imagine the rotating light and the arm movements you have just made. You must close your eyes. Conceptualize and create a mental image of the light and your movements. The movement of the light and your bodily movements should be continuous and fluid.

While you are imaging, you will hear a series of ticks. These ticks will help you imagine the speed at which the light and your arm moved. As you remember from the demonstration, at each tick your arm was in approximately the same position.

It is very important for you to carry out these instructions to the best of your ability. Can you tell me in your own words what I want you to do? You will have 18 30-sec imagery trials. Between trials you will have 30 seconds in which to rest.

When you hear the ticking start, begin mentally imagining the rotating light and your body movements. When the ticking stops, rest. When the ticking resumes, immediately begin imagining again. Create an image for the entire trial that corresponds with the ticks.

Section IV

Please pay close attention; it is essential that you have a clear understanding of what is about to be said. In order to insure accurate and valid testing, it is requested that you not discuss these proceedings with other students.

This is a rotary pursuit apparatus. It is used to measure hand-eye coordination (pick up stylus with left hand). You need to grasp the stylus with the left hand, then assume a comfortable standing position with shoulders facing the apparatus (demonstrate described position). Place the tip of the stylus on the target light (place stylus on target—start apparatus with right hand). To be successful at this task, you must always keep the tip of the stylus on the rotating target. Make one distinct and continuous movement while following the rotating target with the stylus (pursue target). Do not make a discrete or jerky movement (demonstrate). If I were to hand you the stylus right now, would you know what to do with it?

Listen to the ticks on this tape (turn on tape). Note that the light is in approximately the same position whenever you hear the tick (pursue target with tape on for 1 min). Do you have any questions about how the task is performed? Do you have any questions about the relationship between the speed of the target and the ticks on the tape?

Now sit on this stool. You are now to mentally rehearse the rotary pursuit task. Mental rehearsal refers to imagining the task without making any observable movements. Your task is to imagine yourself pursuing the target with the stylus in your left hand. You must close your eyes. Conceptualize and create a mental image of yourself performing this task. For the duration of each practice trial, imagine yourself making a continuous and fluid movement with the stylus. Try to get "the feel" of executing this task by imagining yourself performing this task as precisely as possible. Do you have any questions? While you are imagining, you will hear a series of ticks. These ticks will help you imagine the speed at which the target is rotating. As you remember from the demonstration, each tick corresponds to one revolution of the target. Can you tell me in your own words what I want you to do? You will have 18 30-sec imagery trials. Between trials you will have 30 seconds in which to rest.

When you hear the ticking start, begin mentally following the target with the stylus. When the ticking stops, rest. When the ticking resumes, immediately begin mentally following the target again. Create an image for the entire trial that corresponds with the ticks. Hold the stylus in your left hand and get ready to begin. Do not move the stylus.

Section V

(Instruct subject to read magazines until ready—allow 23 min for Control No-rest—allow 32 min for Control Rest.)

Please pay close attention; it is essential that you have a clear understanding of what is about to be said. In order to insure accurate and valid testing, it is requested that you not discuss these proceedings with other students.

This is a rotary pursuit apparatus. It is used to measure hand-eye coordination (pick up the stylus with left hand). You need to grasp the stylus with the left hand, then assume a comfortable standing position with shoulders facing the apparatus (demonstrate described position). Place the tip of the stylus on the target (place stylus on target and start rotor with right hand). To be successful at this task, you must always keep the tip of the stylus on the rotating target. Make one distinct and continuous movement while following the rotating target with the stylus (pursue target). Do not make a discrete or jerky movement (demonstrate). If I were to hand you the stylus right now, would you know what to do with it?

Listen to the ticks on this tape (turn on tape). Note that the light is in approximately the same position whenever you hear the tick (pursue target with tape on for 1 min). Do you have any questions about how the task is performed? Do you have any questions about the relationship between the speed of the target and the ticks on the tape?

(Give stylus to subject.) Put the stylus on the center of the glass, not on the target. When the target starts moving, perform the task just like I demonstrated. Move the stylus away from the light when the target stops rotating. (Start the performance trials from the control board. As soon as the target stops rotating say "Keep the stylus away from the light whenever the target is not rotating. Get ready to begin again.")

(Give 9 30-sec trials with 30-sec rests.)

Good. (Now debrief, answer questions, remind not to tell others of design, and tell where to put a self-addressed and stamped envelope if summary of results are desired.)

Section VI

(Turn on the tape; wait for warning tick.) Ready? When the ticking starts, begin imaging without making any physical movements.

(at end of trial #1) Stop imaging.

(at end of first rest) Get ready to start again.

(at end of trial #2) It is important to image for the full 30 seconds at the speed indicated by the ticks.

(at end of trial #3) Stop imaging. (wait) Get ready.

(at end of trial #4) You're doing fine so far.

(at end of trial #6) Image for the full 30 seconds.

(at end of trial #8) It is important to image at the speed indicated by the ticks.

(at end of trial #10) Stop imaging. (wait) Get ready.

(at end of trial #12) You're doing fine.

the target stops rotating (start performance trials from the control board—when the target stops, say "keep the stylus away from the light whenever the target is not rotating. Get ready to begin again.").

(Give 9 30-sec trials with 30-sec rests.)

Good. (Now debrief, answer questions, remind not to tell others of design, tell where to put a self-addressed stamped envelope if a summary of results is desired.)