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THE EFFECTS OF INSTRUCTION AS A SECONDARY TASK LOAD ON SKILL IN AN EYE-HAND COORDINATION TASK

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By
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1973

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The dedication of this work extends lovingly and respectfully to my late father, whose value of industry, inquiry, and education inspirationally assisted this work to completion.
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INTRODUCTION

Movement is a function of all life. It appears in various forms, but is more practically recognized in operators of machinery, assemblers of parts, performers of sport skills, and manual laborers of any kind. Implicit in the practical applications of movement are the concepts of skilled and unskilled labor, efficiency and inefficiency in movement, and competency and incompetency in performance. Each of these suggests a developmental process, and each concept interrelates. It follows that to perform a practical movement, one which is directed toward fulfilling an objective, certain learning processes must take place.

The terms "skilled" and "unskilled" represent common classifications for today's labor force, yet the development of skill remains an enigma sought to be resolved by industry and management, the armed forces, and the physical educator among others. For a long time skill was regarded as something one observed and tried to imitate. This method for learning is still evidenced by the training of master craftsmen who apprentice themselves for several years, and children who similarly learn smithery in shops, working at their fathers' side. In the past, psychologists generally regarded skill learning as a part of the S-R theory. Simple chains of movements
began to form larger and more complex movement chains, and that was how movement became skilled. Research efforts have now pointed the way to a new basis for analysis, a systems model approach.

Efficiency has importance with regard to skill when energy costs are a concern. That one can do a job is not always enough. Abundant physical vigor and psychic energy frequently simply supply the necessary requirements for a position. If, however, only qualitative judgements were of concern, the whole economic and industrial scene would be in chaos. For high employment potential a certain quantity of work is expected as well as quality. The more optimally these can be combined, the better the position one might accrue. Efficiency deals mainly with speed and the flow of execution of skills.

The competence of skill suggests a level of attainment such that performance is consistent and of acceptable quality. The several unique elements which compose competent individual performance are, according to Whiting, intention, a period of learning, and complexity which involves chains of sensory, central and motor mechanisms, and each of which has been organized to achieve objectives with maximum certainty.¹ This analysis could resolve many issues, but the complexity question, and therefore the

enigma of skill, remains obscure. It is the dynamic interrelationship of perception, and attention, each considered as a developmental process, which suggests a relative rather than exact measure of skill attainment sought by each learner.

Program designers who train skilled workmen seek efficient and effective methods to develop more skilled workers faster. So long as the skill acquisition process is unclear, attempts at developing effective programs seem without direction. The recent use of models, however, has assisted the understanding of skill acquisition. Through the use of models, time, error analysis, automation, and perception can each be considered in their own capacity at a specific developmental level in an ordered sequence.
CHAPTER I

STATEMENT OF THE PROBLEM

So long as society has need for skilled performance either for pragmatic purposes associated with labor, or for entertainment and recreation in the pursuit of sport, a search for better understanding of the elements of skill acquisition and performance will continue. In the past, a great deal of applied research attempted to investigate teaching methodology by examining organization plans, practice schedules, breakdowns in lesson concepts, ability groupings, and sequences for built-in transfer effects. Each of these represented an observation of a performing population in a specific skill or sport. Conflicting results began to appear when skill levels were independently observed. It soon became apparent that, if research could elucidate the process of skill acquisition, it would have to theoretically establish a model which would not be skill specific, but would apply to all motor skill learning. That model could be developed from existing observations and associated learning theories and then be explored through systematic inquiry as a totality, or part by part as points along the process of skill acquisition.

The most recent attempts at formulating models have
placed emphasis on the developmental aspects of skill. Flexible, interdependent, dynamic systems of industrial production have been used in the formation of systems models to help explain this new thought regarding skills. Provisions were made for the concept of feedback, error correction and detection, perceptual distortion, and other factors which influence the learner. Consideration of engineering through mechanically efficient operations; physiology, by knowledges concerning the limitations of the human machine; and psychology, through the understandings of the capacities of the information processing and attention mechanisms of the brain; has resulted in a more dynamic and adaptive concept. This approach by its broader scope to the understanding of skill aspired to take into account some of the heretofor unexplained variables and their relationships. Models have provided visual representation of processes, and at the same time have illustrated junctures of interdependence with inputs from other possible sources of error. Environmental influences have provided such an error source, causing changes in the system. Thus, it become increasingly apparent that study of the development of skills might increase the efficiency in man's practical movement endeavors.

This study was an attempt to establish three points along the learning process which might illustrate unique performance behaviors at beginning, intermediate, and
advanced movement control levels. It has been a rather widely held notion that as one continues to practice and develop skills, he becomes less susceptible to interference, or the performance becomes increasingly automatic. In addition, therefore, to establishing these sites along the skill acquisition process of an eye-hand coordination task, a secondary task was performed concurrent with the primary task. The secondary task was utilized to identify the extent to which it interfered with performance on the primary task. The secondary task was further input or an added load for the performer and came in the form of instruction of three types; memory dependent or previous instruction, visual instruction, and audio instruction.

The study was specifically interested in determining if the three selected performance sites along the process of skill acquisition were different. Further it was hoped that observations could be made which might support or refute the theory that with a higher level performance subjects have increased spare capacity, due to a more automated performance. Therefore, since the secondary task of visual instruction loads the visual channel, and that channel is already stressed due to the nature of the primary task, performance at the beginning site on the skill learning process would hypothetically be different from the performance at the same site for groups with audio or previous instruction. Further, due to the increased
automation factor associated with a higher performance level on such a continuous eye-hand coordination skill, one might well suspect that the secondary task in the form of three instructional inputs would effect the three skill levels differently. This study attempted to explore these relationships.

It was further hypothesized that the performances of the nine groups, three at each site, will have an ordered effect in terms of the treatments with each group. The effects at each level were not expected to be in different order. The performance means were expected to order themselves with the low visual group being the lowest mean and the high previous instruction group with the highest performance mean. This ordering might be illustrated as follows:

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Hypothesized Ordering of Performance Means

Figure 1
Skills are learned behaviors. Their complexity and performance need to be closely examined in terms of the models presently available. Performers of different competencies are theoretically under different kinds of feedback control as was illustrated with the concept of automation. It was the purpose of this study to investigate the relationships among skill competencies and instructional inputs given during the execution of a continual eye-hand coordination task.
CHAPTER II

REVIEW OF THEORETICAL AND RELATED LITERATURE

The skill learning process has been the subject of much inquiry, conjecture, hypothesis, postulate, and theory. Unfortunately, the past fifty years have produced very little hard fact. In nearly every instance, much research is needed to make application to the skill learning process, and to assist teachers in teaching skills, developing progressions, and planning curricula.

Movement control seems to differ in nature among beginners and more advanced performers. Some have observed that the novice has no control while the expert has polished control. The beginner appears to clumsily "think through" movement while the professional seems to do his activity automatically. With these empirical observations pervading the thoughts of teachers and learners as well, inquiry has been directed toward the resolution of this enigma. When do the controls change? How do they change? Could these high and low performance levels show a difference which might logically suggest a continuum or an impetus to move through a developmental sequence?

Using systems models to elucidate the skill
acquisition process, theory has begun to make a significant contribution to the teacher and the learner. Along with these process oriented representations, movement control was considered as a central issue. In addition to observed control differences, attentional demands at the various learning stages appeared to be different. Each of these aspects were considered in the communication, control system, and adaptive system models which are to be discussed briefly. The movement control methods which might account for performance differences will also be discussed.

THEORIES OF MOVEMENT CONTROL IN SKILL ACQUISITION

Communications Model

The communications model was a quantitative effort to understand performance. The general pattern of this basic research experimentation offered information of a measured quantity in the form of display loads. The output or performance indicated how much of the display was processed centrally, and also how fast. Essentially the information available was measured against the processing ability of the learner.

This model assumed that motor responses have dependable, predictable stimuli, each of which can be inferred from the specific response. These stimuli were
clustered, bunched, or synthesized during a process of information reduction or classification. It was during this process that learners individually expressed themselves in selecting emphases, forgetting, embellishing, and reasoning. Information was created anew when memory was considered in the interpretation of a stimulus, but the locus of the process was not defined or limited. If individuals expressed themselves between the stimulus and the response, the concept of predictability in terms of the stimulus would be difficult to underscore.

Movement control was simply the result of repeated reactions to the discriminated stimuli. As behaviors repeated themselves, efficiency developed due to the nature of man in his quest for conservation of energy.

This model has had limited acceptance in part due to the dichotomous nature of the transmission measurement. Near misses to an objective were not considered quantitatively. As an additional limiting factor, the probability of the stimulus set was assumed to be predictable, but physical education skills are seldom observed as predictable. Within this model there was no provision for error correction specifically measurable since the creation of information, and the recording of the same were considered only in the behavior observation. This meant a potential mis-observation could be reconstructed or corrected, and this whole process take place without a measurable
behavior observation or antecedent for that matter. Ongoing monitoring of performance with respect to speeded tasks was not provided for. In addition, very few skills are behaviors resulting from stimuli which were isolated and within a single dimension, and so the research with respect to this question has had limited generalizability. At best, this theory was continued to generate new types of highly specialized equipment to assist in the performance of skills which specifically involve recognition of discriminated stimuli.

Cybernetic Model

A more recently espoused system developed to help account for several of the problems with the communications model was that of the cybernetic theorists. The basic form of this model involved some input or source of power, a sensing device which measured the output or the activity of the machine and a feedback loop which translated the output measure into a signal which became the input. This method involved the basis for servo-control systems or servo-mechanisms. The feedback loop provided the feature which permitted ongoing control of performance, and, in general, an expected production level, regardless of encroachments from outside the system.

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The cybernetic model employed a closed-loop feedback mechanism to generate a regulated output. Essentially closed-loop meant that there was a circular relationship between feedback and movement. Early in the learning process a movement was made, and its result was checked with a standard which had been learned. This standard has been termed motor command center, image, neural model, perceptual trace, and central program. The first test was a comparison of what was observed with a desired outcome such as the image. Assuming that there was a discrepancy, one operated until the observed and the ideal were more closely approximated. This was once again tested, and if correct, then exit, or the person stopped trying to approximate the disparity. The specific plan of the adaptive behavior processes skill learners perform has been analyzed by Miller, Galanter, and Pribram in a servo-unit they termed Test-Operate-Test-Exit (TOTE).

Questions arose when one considered that the learner was only potentially as good as that initial memory trace. There was no built in device to explain possible modification of the memory trace, but only devices to control and disperse error. It was difficult to see how error-

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centered feedback stimuli could help the perceptual trace modify or maintain itself. Nevertheless, the second testing of the system was made in terms of knowledge of the results of the first, and then the entire process repeated itself.

Although Adams' theory in particular allowed the consideration of some open-loop control with respect to the memory-centered portion of the process that chose and initiated responses, he mainly concerned himself with the closed-loop aspects of movement extent, which were error centered. Skill progressed when these TOTE units became additively more complex in order to help realize more complex activity. In turn, the feedback loops became more generalized throughout the complex activity, and specific monitoring became less necessary.

Holding discussed the role of knowledge of results (KR) in learning. He made clear that all feedback was not KR, but that all KR was feedback. An example of feedback that was not KR was action feedback, where knowledge of the changing state of attempts to produce results simply leaves one more or less able to deal with situations. This was feedback occurring during a serial or continuous task. He also cited that people tended to lose interest


in a task without knowledge of results, whether internal in a kinesthetic loop, or external in praise from a teacher, or visual reinforcement from achieving a goal or purpose.

Annett emphasized that whether one is involved in forming a plan, operating the plan, or correcting the plan, each stage was only as effective as the availability of feedback. He did not contend that KR provided motivation, in part because that conclusion was personality theory dependent. Rather he suggested that since hierarchies of feedback loops illustrated skill development, feedback was essential to the cybernetic model of skill acquisition. His transformation rules outlined how a learner used feedback from a response to guide him to his next response choice.

Research has been done to support the closed-loop nature of learning and movement control. When engineering psychologists examined tracking behavior, they observed human use of a servo-mechanism. As a target moved, the subject, in his attempts to stay on target, outlined jerky movements. Closely examined, according to Vince, the subjects would make a correction every 500 milliseconds in order to stay on the target. That was the average correction factor resulting from output feedback that was observed from the data.

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In a similar manner, but clearly with a different task demand, Keele and Posner trained subjects to move a stylus six inches to a target \( \frac{1}{4} \) inch in diameter.\(^9\) The subjects were trained to complete the movement in 150, 250, 350, and 450 milliseconds. On intermittent trials the lights were shut off as soon as motion began so that movement was completed in the dark. The results showed that subjects were equally successful at hitting the target, with or without the light, at an actual 190 milliseconds speed. Movements 260 milliseconds or slower were aided with light. The aid at 260 milliseconds and slower represents visual feedback help.

Pew has encouraged this view of man as an information processing system.\(^{10}\) He suggested that there be an inner-loop with two tracks, both of which act on the system before the output. Essentially this amounts to both a closed-loop correction path and an open-loop monitoring path. He felt that skilled performance must be analyzed rather than the acquisition process only, and he used mathematical representations to illustrate this relationship.

Movement control has been discussed in terms of the acquisition process, but kinesthetic perceptions and


other intrinsic controls would still appear not to have been taken into account. Several psychologists have sought the role of kinesthesia and peripheral feedback loops as they relate to movement. Wilson's work with the locust helped to elucidate the central involvement of these systems.\textsuperscript{11} He worked with wing control in the flight of the locust, and found that, although he removed half of one wing and left the other intact, the rhythm of both wings was the same, and though differing in size, they experienced similar speed in movement patterns. The flight reflex was initiated by the stimulation of an air stream directed over a few hairs on the locust's head, and the program triggered rhythmically and predictably every time, regardless of whether the wings were on or even completely off. He concluded that there was such a central program, and that there was a specific motor output which was a genetically given program. Kinesthetic and reflex patterns had a dispersed effect on the organism, which meant that the locust would continue to try to fly, even though the weather was bad, or the wind blew hard.

Lazlo and Manning tried to block all peripheral feedback channels for human subjects with a nerve com-

pression block as they performed a tapping task. They still found their subjects somewhat able to learn, and concluded that instructions about a task were translated into motor command units, which in turn were compared with the original memory trace. At no time were their subjects completely dependent upon the peripheral feedback loops. All the subjects performed skilled movement in the absence of proprioceptive and kinesthetic feedback loops.

Taub, Ellman, and Berman, in still another deafferentation study, severed the nerves of a monkey's forelimb, and observed that the limb was not used. However, when they restrained the intact arm, the monkey used the de-afferented forelimb in walking, climbing, and grasping tasks. Extending the study, both upper limbs were altered and the monkeys were observed to conduct normal necessary skills with no problem; they performed even blindfolded.

**Adaptive Systems Model**

The cybernetic system model accounted for both an

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open and closed loop control system, but there was no sequence or temporal pattern established. The third system, the adaptive systems model, seemed to have the greatest amount of acceptance today. Here the theory of the computer was applied to the human system, and a dynamic three-dimensional system was in operation which included consideration of time and space. Gentile has worked extensively with the most outstanding aspects of the communication models and the servo-mechanisms of the human body.\(^{14}\) She has considered space and time in her acquisition model, and has also considered the skill complexity question with the use of Poulton's classification continuum.\(^{15}\) She has broken down the acquisition process into two stages which, as in the cybernetic model, involve an initial closed-loop feedback system and then open-loop control in a later stage.

In the beginning stage the learner establishes a goal, and organizes and formulates a movement pattern to achieve that goal. The individual in quest of a movement goal is constrained by his neurological limitations and capabilities, and must balance accurately the opposing


muscle groups necessary for a movement. All of this begins at birth, and is continually in a process of development until maturity. Unique in Gentile's approach was the necessity for man to adapt himself to the shapes, spaces, time, and flow of the environment in which he operated. The beginning learner needed to establish a group of stimuli which he closely associated with his goal attainment effort. He learned to select these from the many stimuli available to him. Then movement began with respect to the environment in which the goal resided. Certain conditions had to be met before a facsimile of the desired outcome could have been emitted. Gentile called these conditions the regulatory stimulus subset. It is to these stimuli that each learner must be trained to select and attend, apart from all the other momentarily effective stimuli present.

Before the learner actually tried a movement, he had to have some specific notion about the nature of the movement goal. This construct is referred to in the literature as an image, neural model, or movement plan. Gentile also employed the TOTE organizational scheme to establish the motor plan. She used the feedback from TOTE to guide the organization of the next response. When the learner decides, he makes decisions on the basis of

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two levels of feedback, the intrinsic feedback, and feedback resulting from the comparison outcome. Both help him to formulate the motor plan.

After he has a basic grasp of a movement plan, the learner moved to stage two, which was termed fixation/diversification. In stage two, the learner attempted to reach a particular level of skill. In this stage, the original plan might be refined, or it might be extensively changed, depending on environmental influence. If the concern were a closed skill, one with limited environmental influences, then there was low probability that the movement plan would be radically changed. However, if the skill were open, that is, dependent on a changing environment, there was great opportunity to diversify the original plan. The learner must learn a multitude of motor patterns, each to fit the ever-changing regulatory stimulus subsets. There are several general constants even in the open skills, like the size, shape, and weight of an oncoming football, so that one can prime oneself for possibilities which might arise in the environment surrounding the familiar object.

Gentile also developed a systematic classification,

17Ibid., p. 11.
i.e., a taxonomy of skills.\textsuperscript{18} Task variables were observed, and differences were noted in motion types, stimuli vividness, target extent, display extent, background motion, illumination level, and others. At the same time, variables were recognized among individuals with respect to abilities to perceive distance, time, velocity, and acceleration; to predict linear velocity and other complex motions; and to utilize minimum display extent, and different perception methods. She proposed that a task could be given a level of difficulty, depending upon the amount of environmental control, the type of movement required, whether the body remains stable or in transport, and the space per unit time of the moving environmental components. It was this ordering of skills which brought about the performance ordering of treatment groups in this study. Individual performance levels were isolated and considered similarly as Gentile observed the degrees of difficulty of skills.

\textbf{ATTENTION}

Evidence for a kind of control in movement seems clear, although the nature of the same remains obscure.

Extending thought, however, into the problems associated with establishing central control, the first concept to consider is that of attention. Depending upon the complexity of skill, maturation of the learner, and his motivation and attention among others, one can either readily or slowly develop the movement, and therefore the central control mechanisms. If it is assumed that man's capacity for processing information is limited, it follows that as the amount of information to be processed increases, the remaining processing capacity available for attending to other tasks is diminished. More particularly, when two tasks are performed simultaneously, any decrement in performance on one task should reflect the attentional demands of the other. Posner and Keele investigated a task and its attentional demands.¹⁹ They found that of two sizes of targets the smaller one required more attention to maintain contact. When a probe they introduced during the task was acknowledged, the response was delayed more often while staying with the smaller target than the larger one.

In this case it did not appear that movement with any level of precision could be done which would not require attention. The next thought became one of whether

a movement could occur which required no attention. From the target study one might infer that it was the number of corrections and not the movement itself that required attention. Posner confirmed this in a study which was designed to have a peg stop movement. A probe signal at any point during the movement resulted in equally fast reaction times.

Ells investigated the question of attentional requirements of movement controls by analyzing total response time into component parts. He found that directional uncertainty influenced both the movement time and attention to prepare a movement, and that this decision of where to move, and movement control itself appeared to be independent of each other.

Since attention has been specifically identified in both the previous studies and theoretical deductions have been conjectured in order to further understanding, it would be helpful to analyze the term "attention." This was done by Posner and Boies, who developed means for separating attention into three components: alertness,  

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20Ibid., p. 359.

selectivity, and processing capacity. \cite{22} Processing capacity, the third component, was the aspect of interest in this study. A limited capacity was realized when two operations requiring central processing interfere with each other. It is not yet clear which aspects of the operations require central processing, because it could be all of the three components, or just response selection.

Posner and Keele inquired into the attention demands of movements. \cite{23} They began with the assumption that skilled performance had two components: decisions concerning what response to select, and movements to carry out decisions. They were specifically interested in reporting research on the role of attention in the execution and retention of movements. Several observations were made from different sets of experiments having to do with the requirements of attention in skilled performance. One of their first experiments demonstrated that reaction times to extraneous signals are delayed when a subject is executing a movement. \cite{24}

\begin{enumerate}
\item \textbf{24} Ibid., p. 410.
\end{enumerate}
They also showed in the same experiment that this delay was differentially affected by the accuracy of the movement required and the time during the movement the signal occurred. The start and end of the required movement were most seriously affected and as shown before, it took longer to complete an equidistant movement to a smaller target than to a larger one.

From the discussion of skill acquisition, it would appear that beginning skills, or those using the closed-loop method of control would interfere with an attention probe task. However, as movements become more refined and better learned, corrections are not so marked, and movements appear to require very little attention. This approaches an "automated" state, represented by only a few minor corrections in movement not to be handled cognitively. These automated movements, therefore, should not interfere with the processing of a secondary signal, and to illustrate this one need only observe the baseball fielder going after a fly ball, and running onto the warning strip in front of the wall. Such an athlete can attend to other things while running to catch a flyball.

It must first be clear that the concept of automation does not rest on the gradual internalization of cues, but rather on the idea that as ability increases, the need for use of the limited central processing
capacities decreases. Perhaps a way to find how attention is reduced with increased ability, would be to delve into task components which tend to show automation. Furst investigated the possibility of automating the visual component as a result of repeated experiences. He suggested that habituation occurs with practice after he observed many records of visual fixations. To get something automatic, one must reduce the cognitive involvement either by developing more efficient subroutines of classifications, or by decreasing the complexity of what is observed so that one can better relate to past experience. Furst found that visual fixations clearly demonstrate the habituation effect—that there is a significant reduction in the rate of information processing in the visual system. He observed that long fixations increase in frequency during habituation.

Furst's concern was only with the visual channel. The present research effort demonstrated effects of crossmodal competition for a channel. A subject was loaded not only visually, but in some cases both by audio input and an ongoing visual involvement. These results will be discussed later.

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DIVIDED ATTENTION

Divided attention is simply the demonstrated reduction in effectiveness of at least one of two tasks, when both are performed at once. The demonstrated decrement in performance is evidence once again of a limited capacity for processing information in a given unit of time. Basically there are two views of divided attention: sequential and simultaneous. The first requires rapid alternation between at least two sources of information, while the second demands that two sources be processed simultaneously. Whichever the case, Shulman and Briggs demonstrated that the time-sharing decrement was reduced by practice, and that this reduction was more apparent with the more complex signal. Subjects were found to favor the most difficult task with their attention, and so demonstrated some degree of rational control in this process. In addition to the difficulty of the task, an increased load on memory increased the amount of time sharing.

Briggs, Peters, and Fisher attempted to locate the divided attention effect by using the Sternberg additivity

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28Ibid., p. 3.
Making the assumption that human processing of information is in three main categories: encoding, central processing, and output, studies can be found to show that this effect could be in any one of these areas, depending upon the researcher. Briggs showed that this effect was localized in the encoding stage by utilizing a tracking task, which in his opinion did not heavily load any one aspect of processing.

Perhaps the most helpful aspect of the concept of divided attention is that it lends itself as a method for doing research. When two tasks are performed at once, and a payoff is offered to favor one of the two tasks, some involvement of attention can be measured in terms of a decrement in performance. This technique has been used successfully in both memory tasks and in the performance of motor skills. However, Brown cautions against the use of this technique without careful assessment of the nature of the two tasks. The difficulty of a task may be judged on several different criteria, and due to this observation, one must make the assumption that changes in the primary task have comparable interactions with performance on the second task. Brown doubted the validity


of this assumption. He questioned how one could design a subsidiary task which would have the effect of equating difficulty as measured on different criteria. Can one be sure if there is a change in load stress and in speed stress, and that both or else just one will reflect the change? Brown seriously doubted that two tasks can equally influence the operator's spare time. He recommended that one could use a self-paced subsidiary task, which reveals delays in subsidiary responses during peak demands on the primary task. This technique was utilized in the present investigation. Studies in divided attention performance decrements can reveal ways to study capacity limitations, the perceptual process, and might help to clarify the concept of mental load.

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31 Ibid., p. 322.
CHAPTER III

EXPERIMENTAL PROCEDURE

The research discussed in Chapter II provides an approach for examining the processes basic to motor skill performance. Unlike the many lever positioning, tracking, and knob turning tasks previously mentioned, the present experiment represented an effort to more closely approximate the actual performance of subjects in an activity. Gentile's theoretical discussion of skill acquisition coupled with her interest in a taxonomy of motor skills provided the framework for the inception of this study. In addition, the many situations in sport which require one to divide attention aroused interest in the methods used in performance decrement research. Seeing that selected signals could represent a secondary task load, different modes of instructional input were examined in terms of their influence on the primary task.

To represent this primary task, subjects were asked to continuously tap a table tennis ball off a paddle ball paddle as many times as they could. While performing this continuous task, instructions were given every ten seconds to orient either to the right or to the left of the signal light. The effort was to load the kinesthetic channel with
the rather extreme and unique weight differential in the ball and paddle, and the perceptual channel with the continuous, visually dependent task. As a secondary task, three modes of instruction were given. One generally was the control where the subjects had previous instructions so that directional uncertainty was not present. The performance sequence was already rehearsed and stored in memory. The other two modes were audio and visual input, with each having equal levels of directional uncertainty in that the subject goes either left or right on command.

METHOD

Subjects

A pilot test of the ball tapping skill was conducted at the E.G. Shaw Elementary School in Dayton, Ohio on the boys and girls in the fourth, fifth, and sixth grades. It was observed that the fourth graders were in the process of completing their eye-hand coordination development, and so had great difficulty keeping the ball on the paddle with any degree of regularity. On the other hand, the sixth graders appeared to be highly efficient at the task as represented by a rather narrow spread of scores. It would follow that the fifth grade would be the logical selection, and their spread of scores verified the choice. In order to have at least twenty subjects in each cell of the $3 \times 3$ factorial, a minimum of three hundred and seventy
fifth grade students would have to be given the one minute tapping test. This figure depends upon the assumption that the ability levels will evenly distribute themselves in the tested population, and that sixty subjects will fall above one standard deviation to represent the high group, and sixty below to represent the low group. A like number would also be selected directly from the middle of the distribution.

After obtaining permission from the superintendents of the Heath, Granville, and Newark Public School Systems, the principals, and the physical educators in the various buildings, one physical education class was conducted by the experimenter for each fifth grade class. The children were tested on the tapping task for a one minute period. To familiarize them to the task, each child was given two practice trials of thirty seconds. They worked in partners, with one counting while the other tapped. They were encouraged to do their best, and to get as many taps as possible in their minute's time. The performance curve for these three hundred and eighty nine children nicely approximated the standard normal distribution curve, with nearly sixty students above and sixty below one standard deviation. This result is illustrated in Appendix A. Along with the sixty from the middle, these pupils formed the group of selected subjects, each to be tested individually in their schools. Figure II illustrates the numbers and their random assignments to groups.
<table>
<thead>
<tr>
<th>A</th>
<th>B Previous Instruction</th>
<th>B Audio Instruction</th>
<th>B Visual Instruction</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HIGH</td>
<td>23</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>MEDIUM</td>
<td>22</td>
<td>22</td>
<td>20</td>
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<tr>
<td>3</td>
<td>LOW</td>
<td>18</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>63</td>
<td>64</td>
<td>63</td>
</tr>
</tbody>
</table>

A—Skill level  
B—Mode of instruction

**Figure II**

Number of Individually Tested Subjects and Their Group Assignment

**Apparatus**

Three light poles were constructed, with each having three lights. On the square two inch by two inch pole, one light was placed on the right, and the other on the left side. The third light was red in color, and centered on the pole. The pole was built five feet high, because at the distance the subject stood from the light, his focus while tapping the ball most closely approximated this height. The base of the poles were constructed of four
half-inch plywood pieces cut in a trapezoidal shape, and bolted together at ninety degrees to each other. The pole proper was constructed of two one by twos, each grooved in the center to accommodate wiring for the lights.

Three receptacle boxes were housed on the plywood base of each pole, with two being single pole boxes for the lateral lights, and one being the receptacle for the double pole-double throw circuit connecting the center light with a foot switch operated by the subject, and a main switch operated from the console by the experimenter. The foot switch was directly in front of each respective pole as was seen by the subject, and only about a two foot step from his beginning position.

The remotely located console contained a circuit breaker, and three sets of switches, each set composed of two single pole single throw switches to operate the lateral lights, and one double pole double throw switch to operate the center red light. Although silent switches were preferred, the mercury switches were found to operate only in a vertical position, so click switches were used. For convenience, the console contained a false bottom to house the wires connecting the poles to the console. The poles were located twenty two feet apart equidistant to form an equilateral triangle. The subject stood directly in the center of the triangle, in easy reach of the three foot switches.
A standard cassette tape recorder was located on the same table as the console, with the microphone attached to the nearest pole. All sessions were recorded, with each subject being introduced. The sound of the ball on the paddle was distinct enough to be clearly discernable on the tapes, and countable after the session. An illustration of the test situation appears in Appendix B.

**Primary Task**

The primary task which was performed by all selected subjects, required that each tap a table tennis ball with a paddle tennis paddle as many times as possible within one minute of time. In addition they had to acknowledge the red light signal in the center of each pole by shutting it off with the foot switch.

**Secondary Task**

This task was simply one of orienting to the right or to the left when instructions were given. The subjects at each of the performance levels were divided into three groups. Each group received a different kind of instruction. One group was told in coded form (LLRL) which was practiced before they began tapping which way to turn after they shut off the red signal light. The other two groups were not told which way to turn until after they acknowledged the red signal light with the footswitch. They were then
signalled or told by the experimenter whether to go to the left or the right.

**Procedure**

After the three subgroups were established, they were randomly assigned to treatments. Figure II has illustrated this assignment. Directional sequences were randomly chosen and were randomly assigned to subjects and treatments.

The subject entered the room, and was equipped with a ball supply in an apron which was tied around his waist. He was also handed the paddle, and asked to stand upon the "X" which marked the center of the triangle. He was asked to face pole number one, and take a thirty second practice trial at tapping the ball, just as he had done in his physical education class. He was told that he should get a new ball from the apron should one get away from him during his tapping. He was encouraged to reach in the apron rather than chase after a dropped ball. At the completion of the thirty second trial, he was relieved of the paddle, and introduced to the red light and the footswitch on pole number one. His instructions were that should the red light turn on, it was always his job to shut it off. The subject then practiced this procedure, stepping on the foot switch to shut off the signal light. If the subject was assigned to the previous instruction treatment, then next he was given his code.
This code, randomly assigned, would be something similar to left-right-left-left. The subject would be asked to repeat the code several times, and then, on the command "turn" from the experimenter, he would be asked to turn according to his code sequence. After rehearsing the sequence, the subject was asked if they felt that they knew the sequence. With an affirmative reply, the experimenter gave the subject the paddle in his preferred hand, and asked that the subject pretend that he was tapping the ball with the paddle, but to be sure to shut off the red light should it light up. The subject was cautioned not to stop tapping until they heard the experimenter say "stop." The pretend tapping began with the signal "Ready? Begin." After the subject had practiced once through, and had had the opportunity to become familiar with the light timing sequence and his turning sequence with respect to this timing as well, the subject was asked if he had any questions. The subject was then asked to take out a ball, and to begin tapping when he heard the signal "Ready? Begin."

Each subject was introduced onto the tape, was asked if he was ready, and then he was signaled to begin tapping the ball. In ten seconds the red light on pole number one was lit by the experimenter, and shut off by the subject. He turned toward the pole to his left, and looked for the red light to turn on, which happened ten
seconds after the first red light was turned on from the console. He shut off the red light, and turned right toward that pole, and waited to see the red light. During the entire process, the tapping was recorded, and the signals were given each ten seconds until the fifty-second signal. At this point the subject simply shut off the red light, and continued tapping with no further signals until he was told to stop.

The only apparent difference with the audio and visual treatments was that instead of the subjects knowing which way to turn by means of a memorized code, these groups were told either visually with the lateral lights on the pole, or audibly with signals from the experimenter to turn left or right. This instruction was given immediately after the subject acknowledged the red signal light. The trial was defined as successful completion of the secondary task.

**Analysis of Data**

A three by three factorial design was used to identify relationships of performance level with the instructional treatments. Some mention concerning statistical regression in terms of the use of extreme groups might appear legitimate, but two precautions were taken to protect the internal validity: first, each group was distinct, clearly defined, and statistically not alike; second, use was made of a middle group. If there were any
reason to suspect regression occurring atypically, a test could be run for the homogeniety of regression. This procedure, however, proved unnecessary.
**CHAPTER IV**

**RESULTS AND DISCUSSION**

**RESULTS**

**3 x 3 Complete Factorial**

Skill performance and method of instruction acting as a secondary task load were the two independent variables in this study. Each of these had three levels, which provided a total of nine cells with nearly twenty subjects in each cell. The study not only considered differences within the skill factor, but also differences which might arise due to the effects of the secondary task. The skill—treatment interaction was not expected to be significant because the randomly assigned groups for each cell were initially well defined. Figure II on page 34 illustrates this design.

**Manova**

A multivariate analysis of variance was used to analyze the data. The F-ratio was significant at the .001 level of confidence for the main effect of skill performance. This represented the only statistically significant result of the study, as there was no difference among the main effect of secondary task load. These results are illustrated in the source table below.
A least means squares analysis was computed for each type of instruction in an attempt to identify trends in performance from the beginning to advanced levels. The combined graphs illustrate little difference in performance at a given level for the three methods of instruction. The sampling was of such a narrow range that the curves were unable to illustrate the differences observed in the means. These results were illustrated along with the 95% level of confidence limits in the Appendix.

DISCUSSION

The statistical results of the main effect of skill performance seemed expected. However, the F-ratio of the main effects of the different methods of instruction of the secondary task did not show statistical significance.
The result did merit further examination and discussion.

An assumption was made that the three performance levels could be viewed as distinct points for analyzing the skill acquisition process. The observations provided by these points suggested relationships to both theoretical and practical research findings.

Briefly, and to generally review, the initial stages of skill acquisition are characterized by cognitive involvement and closed-loop movement control. This process is generally viewed as error-centered. The number of corrections necessary at this stage are many, and each requires attention. At this point there is also a demand upon the perceptual system, both extrinsic and intrinsic, as the idea of the movement gets developed. The most important stimuli are selectively attended to and attempts are made to isolate the necessary environmental knowledges for the execution of the movement. The learner hereby formulates a movement plan.

The repetitive eye-hand coordination task of ball tapping as many times as possible appears, in the beginning level, to be under direct feedback control. The subject visually monitors the ball very carefully, and analyses outcomes of each tap. He then initiates a correction, usually in the form of a very angular movement to reorient the surface of the paddle. Feedback is once again analyzed, and the process repeats itself. At the novice level, this
task illustrates the jerky movements associated with closed-loop movement control.

Taking a look at the experimental observations at the low performance level, the greatest difficulty incurred by the learner was a visual load as provided by the secondary task. The visual load group performed worse than the group who had previous knowledge about directional turns. There was an even greater difference between the means of the audio and visual group. The obtained result in terms of ordered means appears in Figure IV.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>Memory</th>
<th>Audio</th>
<th>Visual</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>113 1</td>
<td>4 107 1 107 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>83 5</td>
<td>4 84 7 13 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>60 8</td>
<td>7 62 5 53</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure IV

Obtained Order of Means

The poor performance of the subjects at the beginning skill level with a visual load as their secondary task seems understandable in view of cited research observations. The group with previous instructions needed no attention to retrieve their coded information.
They knew exactly which direction to turn after they acknowledged the initial signal. The visual group was uncertain of the signal direction which they had to execute within a limited amount of time. Further, the signal was given with lights which interfered with correcting and monitoring processes necessary to the repetitive task. It was empirically observed that some of the subjects in the visual group delayed their response to the directional signal until they felt they could respond with control. This behavior is characteristic of sequential processing and movement controlled by feedback from the visual system.

At the beginning level, the audio group and the group with previous instruction were not different. Yet, one group is memory based, and the other is uncertain as to their audio instruction. Information retrieval takes no attention, but uncertainty associated with the audio signal requires attention. Why then the difference between the hypothesized and observed findings? It would appear that the audio signal could make use of a free and open channel. At the same time the audio groups were the most vulnerable to experimenter involvement and possible bias because the directions were given verbally, as "left" or "right." Considering that the code might have had to have been rehearsed by the subject with memory based instruction, it seems reasonable that performances with the audio and
previous instruction could be similar.

A second point along the skill acquisition process was identified as that of the average performer. Gentile has not specifically discussed "average" as a stage, but according to the systems model she developed, inferences can be made in terms of the learner's experience. The movement plan and the image are being further refined and clarified. The regulatory stimulus subset has been fairly well defined, and attention is better able to be trained and controlled. The learner finds a bit more control at his disposal. He acts on fewer specific TOTE operations, substituting more general programs which require fewer corrections of a closed-loop nature.

The data observed at this point are interesting. The group in the audio method of instruction did the best, but was quite similar in score to the group which had been given previous instruction. As with the beginning level, it might be observed that there is no attention used in retrieval from memory, but rehearsal to remember takes attention. In spite of the uncertainty within the audio input, the subjects did not need to listen to any other input, so the channel was open, and performances appear quite similar.

The third observation point might illustrate the most skilled performer of the acquisition process. He is fixating and diversifying his responses; his
corrections aren't so numerous. This ball-tapping skill requires very little change in the regulatory stimulus subset, so that attention is free to take in other problems which might arise while he performs. His movement at this point is more habitual, or automatic; it would appear open-loop in nature. Since the subject favors the more difficult task with his attention, the instructional input that requires attention of a specific time would seem to result in the worst performance. Since directional uncertainty influence both movement time and attention to prepare a movement, the hypothesized result of this group of proficient performers seemed to be certain.

The experimental data from the highly skilled performers suggest a marked drop in the demands placed on the central processing mechanisms. The group with previous instructions scored much higher than either of the other groups. Corrections in movement with respect to the primary task seem far less frequent, and very carefully controlled. Strategies were adopted to plan time and increase the potential time to tap the ball. Signals were intentionally delayed in more cases, while others tapped very quickly for the first part of the ten second interval until the signal light came on, then they stopped, shut off the light, and turned, and then started tapping very quickly again. The worst performing group of the highly skilled performers was the visually instructed group. The
time-sharing effect or decrement in performance was most clearly evidenced in this group. However, there was essentially no difference between the audio and visual groups. Perhaps the element of uncertainty in the instructions, taken as a whole concept, had a specific effect at this performance level. The audio and visual groups, unlike the memory coded group, could not plan ahead.

SUGGESTIONS FOR FURTHER STUDY

One method to obtain more clearly defined differences among the treatment groups might be to increase the load demanded in the secondary task. This could be accomplished by having the signal issued at irregular intervals within a tolerable limit at each performance level. Another way would be to increase the speed of responses to the primary signal lights, working with seven second intervals rather than ten. With respect to the secondary task, another alternative could be added to the choices of left and right. The subject could simply stay in that site for another time sequence. The added uncertainty would appear to provide a clearer picture of the secondary effects.

Testing procedures could have been more standardized. During the screening test in the physical education class, the ball supply was limited to the one ball they were tapping. If the ball got away from them, they had to chase
it, sometimes quite a distance, which cut short their chances at high scores on the classification trial. As a consequence, very little time-sharing effect was noted. A better strategy would have been to include the classification in the individual session, and process the data in rank order. Further study in the area of skill acquisition seems necessary to develop the theory and suggest best methods for assisting the learner in his efforts.
APPENDIX B

Model of the Test Apparatus
(from above center)

A--foot switch
B--light pole
X--Ss
E--experimenter
C--console
D--Tape Recorder
F--Microphone
APPENDIX C

Previous Instruction—Low to High

B—represents least error about the mean for scores with previous instructions.

--- line represents the limits of the equation within a 95% level.
APPENDIX C (continued)

Visual Instruction—Low to High

--- represents least error about the mean for scores with visual input.

--- line represents the limits of the equation within a 95% level of confidence.

X = Original Score
APPENDIX C (continued)

Audio Instruction—Low to High

D---represents least error about the mean for scores with audio input
---line represents the limits of the equation within a 95% level of confidence

\[ Y = \text{skill performance with audio instruction} \]

\[ X = \text{Original Score} \]
APPENDIX C (continued)

Three Curves Compared

Illustrates that there is little difference in performance at a given skill level for the three modes of instructions.
BIBLIOGRAPHY


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