The Effects of Proprioception and Extended Practice Sessions on Anticipatory Timing

Bruce H. Turner

The College at Brockport

Follow this and additional works at: https://digitalcommons.brockport.edu/pes_theses
Part of the Sports Sciences Commons, and the Sports Studies Commons

Repository Citation
https://digitalcommons.brockport.edu/pes_theses/28
State University College of New York  
Brockport, New York

Graduate Committee of Physical Education

Title of Thesis: The Effects of Proprioception and Extended Practice Sessions on Anticipatory Timing

Author: Bruce H. Turner

Read and Approved by: __________________________________________

Date Submitted to the Graduate Committee: _______________________

Accepted by the Graduate Committee of Physical Education, State University College, Brockport, New York, in partial fulfillment of the requirements for the degree of Master of Science in Education (Physical Education).

Date ______________________  Coordinator of Graduate Study
CURRICULUM VITAE

Name: Bruce Howard Turner

Permanent address: Jamestown, New York 14701

Degree and date to be conferred: M.S. 1977

Date of birth:

Place of birth: Rockville Centre, Long Island, New York

Secondary education: Valley Stream Central High School
Valley Stream, New York, 1964

Collegiate institutions attended
State University of New York
at Brockport

Degree Date of Degree
B.S.E. 1968
M.S.E. 1977

Major: Physical Education

Professional positions held: Health and Physical Education
Instructor
W.T. Clarke High School
East Meadow, New York
1968-1970

Assistant Professor
Jamestown Community College
Jamestown, New York
1970
TURNER, Bruce. The Effects of Proprioception and Extended Practice Sessions on Anticipatory Timing. M.S. in Ed. 1977 (Dr. Barry Shultz).

Utilizing arm velocity to generate varying levels of PFB, various aspects of the body's timing mechanism were researched. Performance on a coincident timing task was studied with and without KR over a four day period. The experimental design consisted of three groups, 25 subjects each, receiving either high, low or zero amounts of PFB. The response was a right hand timing task preceded by a PFB generating left hand movement. The results indicated that PFB provided for more accurate and consistent responses. Increased levels of PFB resulted in significantly more consistent responses, and in more accurate responses. Accuracy responses were significant between the movements groups and control group, but not between movement groups alone. The groups receiving KR were significantly more accurate than the NKR group but no differences were revealed for KR and NKR groups for variable error. The potential formation of a perceptual trace during KR trials may have allowed for greater consistency once KR was withdrawn. Performance over days indicated that extended practice is necessary for the most effective use of PFB. The day factor also provided possible evidence for a two stage theory of timing in which both input timing and motor programming are utilized.
THE EFFECTS OF PROPRIOCEPTION AND EXTENDED PRACTICE SESSIONS ON ANTICIPATORY TIMING

A Thesis

Presented to

The Graduate Unit of the Faculty of Physical Education
S.U.N.Y. College at Brockport
Brockport, New York

In Partial Fulfillment of the Requirement for the Degree Master of Science in Education (Physical Education)

by

Bruce Turner
November 1977
ACKNOWLEDGMENTS

The author would like to extend his sincere thanks to his wife, Ginnie, for the many hours she spent proofreading and typing this manuscript. A special thank you is extended to Kaye Young for typing the final manuscript.

Computer time was provided by the Academic Computer Center, State University of New York, College at Brockport.
# TABLE OF CONTENTS

**ACKNOWLEDGMENTS** ........................................ ii

**LIST OF TABLES** ........................................... v

**Chapter**

I. **INTRODUCTION AND STATEMENT OF PROBLEM** .................. 1

II. **REVIEW OF RELATED LITERATURE** .......................... 12

III. **PROCEDURES** ............................................. 33

   INSTRUMENTATION ........................................... 33

   RESEARCH METHODOLOGY ....................................... 34

      Selection and Assignment of Subjects .................... 34

      Administration of PFB ................................... 35

      Measurement of Performance .............................. 35

      Administration of KR and Schedules of Practice ....... 37

DATA ANALYSIS .................................................. 37

IV. **RESULTS AND DISCUSSION** .................................. 39

   CONSTANT ERROR ............................................ 40

      Results ................................................ 40

      Discussion ............................................ 44

   VARIABLE ERROR ............................................ 51

      Results ................................................ 51

      Discussion ............................................ 54

   ABSOLUTE ERROR ............................................ 58
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS</td>
<td>68</td>
</tr>
<tr>
<td>A. SUMMARY</td>
<td>68</td>
</tr>
<tr>
<td>B. CONCLUSIONS</td>
<td>74</td>
</tr>
<tr>
<td>C. RECOMMENDATIONS</td>
<td>74</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>76</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Repeated Measures Analysis of Constant Errors in Anticipatory Timing</td>
<td>41</td>
</tr>
<tr>
<td>2.</td>
<td>Simple Main Effects of Groups at each level of Factor B (blocks)</td>
<td>42</td>
</tr>
<tr>
<td>3.</td>
<td>Simple Main Effects for Groups at each level of Factor K</td>
<td>43</td>
</tr>
<tr>
<td>4.</td>
<td>Simple Main Effects of Groups at each level of Factor D</td>
<td>44</td>
</tr>
<tr>
<td>5.</td>
<td>Repeated Measures Analysis of Variable Errors in Anticipatory Timing</td>
<td>52</td>
</tr>
<tr>
<td>6.</td>
<td>Repeated Measures Analysis of Absolute Errors in Anticipatory Timing</td>
<td>60</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION AND STATEMENT OF THE PROBLEM

A great deal of previous research on motor skills, particularly reaction time, had prohibited the subjects from anticipating. In doing so, researchers ignored an important aspect of motor behavior. It was not until 1960 through the work of Adams and Xhignesse that anticipation and timing ability was recognized as independent from reaction time. With this difference clearly recognized, the problem confronting researchers presently is to determine how people acquire such precise timing skills that are demonstrated in many of the perceptual-motor skills performed today.

The importance of timing in the performance of motor skills need not be explained. It is the origin of the body's timing mechanism which is the mystery. In many sport activities, success or failure is determined by the participant's ability to have his/her body, or parts of his/her body, in the right spot at the right time. To accomplish this, the participant has to be able to judge the appropriate time to elicit a movement in relation to, or coincident with, an internal or external stimulus. He or she must also possess the ability to organize the various components of a skilled act into the proper sequence. The performer must then execute the various components of the skill at the proper time. The ability of the performer to execute the skill components
at the proper time is indicative of his/her timing ability and is an essential ingredient for high levels of perceptual motor skill performance.

Timing skill is exhibited when there exists a close interaction between a performer and the temporal demands of his/her environment. According to Conrad, timing is "creating the most favorable temporal condition for response."\(^1\) Correct timing is essential in at least two different situations. The first being when a response has to be performed coincidently with some external event (e.g. batting a baseball). The movement depends upon the proper anticipation of the arrival of the ball. With the proper anticipation of the stimulus, the performer is able to plan his/her response and elicit it coincident with the arrival of the stimulus. A second situation exists when there is no overt stimulus and is concerned with the movement of various parts of the body in the proper direction and at the proper time. The result is a smooth, coordinated and efficient body movement.\(^2\)

Many names exist for the same type of timing. The following are appropriate for the two basic types. Tyldesly and Whiting\(^3\) refer to a response that is made coincident with an external event

---


\(^3\) D. A. Tyldesley and H. T. A. Whiting, op. cit., 162-169.
as input timing. Glencross\textsuperscript{4} after reviewing the work of Provins\textsuperscript{5} referred to this anticipatory timing as positional timing. The sequencing and phasing of response units has been called operational timing (Tyldesley and Whiting) or serial timing (Provins; Glencross) by those authors. This study will be primarily concerned with input timing although serial timing will necessarily be a component of the rather molar task selected.

The serial view of timing hypothesizes that the sequential structure of a skill is centrally represented and can lead to movements even in the absence of peripheral feedback.\textsuperscript{6} The serial timing theory has two components. The first is sequencing. This is the organization or ordering of response units into the most effective sequence. The second component is called phasing. Phasing is the temporal structuring or patterning of the response units once they have been placed in sequence. Each response unit must be placed into the appropriate temporal sequence and occur at the appropriate moment in time in relation to the other units making up the response.\textsuperscript{7} Support for the serial view of timing has been provided by Summers.\textsuperscript{8}

A second explanation of the timing phenomenon is the perceptual or coincident timing theory, (which includes input timing). It is


\textsuperscript{7}D. J. Glencross, op. cit., 765-776.

\textsuperscript{8}Jeffrey J. Summers, op. cit., 229-241.
with this theory that this paper will be concerned. The perceptual theory hypothesizes that the body uses information received via proprioceptive feedback to cue a timed response coincident with an external event. This theory offers two hypotheses in an attempt to explain how proprioceptive feedback is utilized in anticipatory timing, the decay hypothesis and the input hypothesis. The decay hypothesis states that "the occurrence of a response at time \( t \) is assumed to generate a time varying stimulus trace and the stimulus trace at time \( t + \Delta t \) is the cue set to which the subject learns the response that is anticipatory to the environmental event by being initiated without a specific environmental cue."\(^9\) The alternative to the decay hypothesis is the input hypothesis. This hypothesis as stated by Schmidt concerns "using the pattern of input or inflow of PFB from the earlier portions of the response to cue the later portion" (of the movement). The PFB generated from a movement produces a time reliable pattern which acts as a triggering agent for an automatic response once a learned stage is reached for the movement. The input hypothesis predicts that the timing of later portions of a movement will be enhanced if greater proportions of PFB are experienced in the earlier portion of the movement. It is extremely important, however, that the input of PFB be kept consistent from trial to trial in order for it to be a reliable cue.\(^10\)


This study had two main objectives. The first was to identify the role of proprioception and specifically proprioceptive feedback in a coincident timing task. If proprioception is necessary for the performance of an accurate anticipatory timing task, then by manipulating control device dynamics thereby altering the levels and discriminability of PFB, could accuracy of the timing task be increased? In this study, arm velocity was the manipulated proprioceptive variable. Whereas the majority of previous studies in the area of anticipatory timing utilized loading techniques, and varying amplitudes of movements to induce PFB, the present study utilized velocity of left arm movement to generate PFB. The manner in which velocity generates PFB was provided by Skoglund in 1956. He stated that receptors increase the frequency of firing according to the velocity of the movement. The rate of firing of individual receptors can be influenced by the degree of tension or rotation applied to the joint by muscles. Thus it was postulated that the increased inflow of information would provide for a more discriminable cue.

Rate of input has been shown to affect temporal anticipation where the interval is predictable. Schmidt (1969b) varied the speed of movements, the distance, and used inertially loaded movements to increase the movement time. The faster movements, loaded or unloaded, the shortest movement distances resulted in decreased mean absolute error.

The second major objective of this study involved determining the effects of extended practice sessions on the learning of a coincident timing response task. The study used a velocity control device to manipulate the proprioceptive feedback and investigated the impact on accuracy and learning. The findings suggested that increased practice sessions led to improved performance and enhanced learning of the coincident response task.

timing task. Specifically, to investigate the role of PFB in different stages of the practice session.

A subproblem investigated in this study was the effect of knowledge of results (KR) in different learning stages. An attempt was made to support Adams' statement that in the early stages of practice, KR should prove beneficial to the learning process. In fact, withdrawing KR when the level of training is low or moderate will result in a deterioration of performance. However, after a relatively large amount of training, learning can continue when KR is withdrawn. Withdrawal of KR is merely a change in the learning condition. Past learning has its influences but learning still takes place when the task conditions are changed. Each time a movement is made a perceptual trace is formed, regardless of the presence of KR. The reason for withdrawing KR in this study was to assure the experimenter that the only cues the subject responded to are those generated by proprioception.

Proprioceptive feedback has been extensively investigated to determine its role in coincident timing. These studies have, by manipulating sensory and perceptual variables and temporal uncertainty, investigated the manner in which a subject can anticipate the time course of events as indicated by the discrepancy between the response


14 Jack A. Adams, op. cit., 111-149.
and the signal. One of the earliest mentioned works involving timing in skill performance was that of Helson in 1949. Using a continuous tracking task, he demonstrated that subjects could anticipate the arrival of an external stimulus and respond to it in less than the normal reaction time standard. The question which has gone unanswered since then is how the body operates its timing mechanism in order to obviate any time lag which might occur. Schmidt's explanation of the body's timing mechanism, with regard to the decay theory of anticipatory timing, consists of three testable predictions. 

1. By increasing the force or amplitude of PFB, a larger stimulus trace will enter short term memory and thus be a more discernable cue as it decays; 
2. the PFB must be consistent from trial to trial so that it decays to the specified level in the same time duration; and 
3. the greater the absolute amount of decay, the more accurate timing will be, and since decay is theoretically an exponential function of time, the shorter the interval, the more accurate the estimate.

An investigation of peripheral timing which purportedly supported the decay hypothesis was Adams and Creamer's study in 1962. In this step tracking task, they claimed support for the decay

---

hypothesis when they found that shorter intervals and spring tension produced more accurate timing results. Christina, 1970,\textsuperscript{18} recognized some deficiencies in this study. The PFB generated from the spring tension may have created a mechanically more favorable system for responding. The methodological factors of the experiment also favored the experimental group. Recognizing these deficiencies, Quesada and Schmidt,\textsuperscript{19} had the subject's left arm passively moved down a trackway. Two seconds after the end of the movement, the subject had to depress a button with his right hand. The groups receiving PFB had a significantly smaller mean absolute error than the group which received no PFB. These results supported the decay hypothesis. Cummings and Santa Maria\textsuperscript{20} investigated the role of vestibular feedback and their results were the same as Quesada and Schmidt's. The subjects receiving feedback had significantly smaller absolute errors than those who did not receive feedback.

Other studies in the area of peripheral timing include those conducted supporting the input theory. In 1968, Ellis, Schmidt, and Wade,\textsuperscript{21}


manipulated amplitude and tension in a time estimation task. Significant effects were found for amplitude manipulation, but not load manipulation. The results of load manipulation were contrary to the experimenter's expectations. Ellis, 1969\textsuperscript{22} varied tension, acceleration, and velocity and found these conditions to be superior in timing accuracy and response consistency than conditions of no resistance. Schmidt and Christina,\textsuperscript{23} 1969, varied angular displacement and found no significant differences between their medium and high feedback groups. In 1971, Christina manipulated load and amplitude and found no significant effects. One year later, Christina found support for the input theory when his high feedback group temporally anticipated with greater accuracy than did his low feedback group. In Christina's 1970 study, he failed to demonstrate the superiority of either the input or decay theory of anticipatory timing. A possible cause of this was not keeping the PFB consistent from trial to trial. Shultz,\textsuperscript{24} 1974, utilized a mechanical device to insure consistent PFB from trial to trial. Studying velocity cues as a source of PFB, Shultz attempted to


\textsuperscript{24}Barry B. Shultz, "The Role of Proprioceptive Feedback in Perceptual Anticipation and Coincident Response Timing," (Doctoral Dissertation, University of Maryland, 1974).
demonstrate the superiority of either the decay or input conditions on performing a coincident timing task. The results demonstrated that the input and decay conditions both of which received PFB, did not perform significantly different relative to accuracy, consistency, or rate of learning to time, than did the control group which received no PFB.

The similarity of the decay hypothesis and the input hypothesis is evident in the function of PFB. Both hypotheses are dependent upon receiving consistent levels of PFB. Regarding the decay hypothesis, input PFB levels should be consistent, allowing it to decay to a specific level in the same time period of each trial. The input hypothesis utilizes PFB as one of the factors in establishing what Adams refers to as the "perceptual trace." The PFB generated from the subject's last movement leaves a trace which acts as a reference point for the next movement. The proprioceptive feedback from the next movement is compared to the reference point in order to detect and correct errors while the movement is in progress. In this closed loop process, PFB should be consistent from trial to trial, insuring a stable perceptual trace and reference point.

The task used in the present study required that the subjects learn a time interval and respond coincidentally with an external event. By not knowing beforehand what the time interval was, the subject was required to use anticipatory timing skills rather than time estimation ability.

This investigation proposed a two stage theory of timing. Initially, the subjects will be dependent upon verbal and proprioceptive feedback to guide their performance. In the later stages of practice, there should be a shift from the performer's dependency on proprioception to that of a motor program.

Delimitations

The subjects were right-handed male physical education students from Jamestown Community College, Jamestown, New York. Their ages ranged from 17 - 38. Previous athletic experience of the subjects included none to varsity team members. None of the subjects had any previous experience with the apparatus being used. For the purpose of this study, it is to be assumed that proprioception is a component of the body's timing mechanism and that PFB is a variable which can be manipulated.

Limitations

There was no direct evidence that the subjects were not employing other potential strategies to facilitate timing performance (e.g. counting, self-induced PFB etc.). In addition, there is no clear evidence that velocity was the only cue being used by the subjects. Positional cues, force cues, and duration cues are other possibilities. Since direct recordings of the sensory afferents and motor outflow were not measured, the possibility of timing being controlled by other sensory information or corollary discharge (motor efferents) must still be maintained.
CHAPTER II

REVIEW OF RELATED LITERATURE

This review of literature is comprised predominantly of those studies concerned with proprioceptive feedback and its relationship to anticipation and timing abilities. The review has been organized so that the reader may follow the evolution of the two most viable input theories used to explain the body's intricate timing mechanism. These two hypotheses are the decay and the input hypothesis.

The first section of the review presents the reader with some general timing studies and shows the early attempts of establishing a relationship between proprioception and timing ability. Another section deals with the role of knowledge of results and learning timing tasks. This is followed by literature dealing with at what time in the learning stages are various individual abilities more important than other ones. The last section of the review presents information regarding both the decay and input theories of anticipatory timing, the theories themselves, and supporting evidence of both.

Early studies indicated that motor performance was to a large extent based upon one's timing ability. Bartlett, in 1951, demonstrated that as a pilot's fatigue level increased, his performance as a pilot decreased. He attributed this decrement in performance to the

pilot's inability to control the components of his inner timing mechanism. Poulton\textsuperscript{27} had subjects trace a path from one target to another and back again as fast as possible. The starting point was the center of a circle and the targets were on the periphery of the circle. The subjects had to trace from the center and back again for each target. An increase in smoothness in performance of the subjects was attributed to improved timing accuracy. Using tracing tasks which involved repeatedly moving a stylus from the center to the end of one of several peripheral tracks and back again as fast as possible, Leonard\textsuperscript{28}, manipulated event certainty by specifying which track would follow arrival at the center. If the subject was at the periphery when the information was given, he spent much less time stopped at the center and moved much more smoothly and rapidly than if this information was given at arrival at the center.

Time estimation or time perception is a phenomenon related to timing using various methodologies. Clausen (1950), Goldstone, Boardman and Lhamon (1958), Goldfarb and Goldstone (1963), and Dimon (1966) all investigated this phenomenon. Clausen\textsuperscript{29} investigated the ability to judge short time periods. The apparatus used in the experiment was an electrically driven stop clock attached to a light and key. The clock and light were engaged with depression of the key and disengaged when the key was released. The light could be replaced with a buzzer to produce either filled or unfilled intervals. The subject's


task was to either estimate the duration of a time interval (verbal estimation group), reproduce random time intervals of 5, 10, and 15 seconds (reproduction group), or was to depress the key for an interval stated by the experimenter (operative estimation group). Performance of the filled intervals were compared to performance on the unfilled intervals for all three groups. None of these comparisons revealed any significant differences. The method of verbal estimation consistently resulted in overestimation while both the methods of reproduction and operative estimation showed continued underestimation for the 10 and 15 second task and overestimation for the 5 second task. Verbal estimation yielded the least accurate results of all the groups. Although the method of reproduction was the most accurate, it also had the largest variability and lowest reliability over the testing period. Clausen concluded that the method of operative estimation was favored over the other two. The subjects for this experiment were 43 schizophrenic patients.

Goldfarb and Goldstone\(^3\) conducted a study to compare three psychophysical methods that permitted subjects to judge the duration of one clock second. The three methods were adjustment, production, and estimation. The adjustment group regulated a metronome beating through headphones to their concept of one beat per second. Before making any adjustments, the metronome was already beating at this rate. In the production group the subjects were to produce a minute by counting orally one count per second. The estimation group was to

estimate ascending and descending auditory durations as more than or less than their conception of one second. Ten subjects received all three methods. The least accurate results were obtained from the estimation group. The adjustment group was significantly better than the estimation group as was the production group. However, there was no significant difference between the adjustment and production groups.

Whereas Clausen (1950) and Goldfarb and Goldstone (1963) investigated time estimation, Goldstone, Boardman and Lhamon\textsuperscript{31} offered the first relationship between proprioception and time perception. They had young children, college students, and older adults estimate 30 seconds. The subjects were divided into two groups. One group was allowed to count. The counting group proved to be more accurate than the silent group. The accuracy is attributed to the greater amount of proprioceptive feedback received due to the muscular actions of the mouth and throat while counting. Further support for the involvement of proprioceptive feedback was evidenced when many of the subjects in the silent group created movements of their own which the authors assumed aided them in their task. The authors concluded that the estimation of a period of 30 seconds was dependent upon PFB. The authors also speculated that younger children were not as accurate in estimating 30 seconds because they had not had enough experience in timing matters or situations to be cognizant of the relation between events and time duration.

Using divided attention methodology, Dimond attempted to show that improvement in performance of a reaction time test was due to the body's

In addition, if the body is utilizing PFB to aid in its timing task, the more consistent the PFB, the more valuable its role in timing tasks. In Dimond's study, the subject's task was to react to a signal (light flash), with their left hand. Reaction time was recorded for this task. An additional task (tactile) was to reposition a key with the right hand when it was displaced. The subjects were divided into two groups. Both groups received signals for the key positioning task at a rate of sixty signals per minute. One of the groups received regular signals for the reaction time task at ten signals per minute. The other group received irregular signals for the reaction time task at ten signals per minute. Dimond predicted that if the subjects were presented with two tasks having separate signal sources, a reduction in time uncertainty on one task would not only allow the facilitation of performance on that task but a similar improvement should also occur on an additional task performed simultaneously. A significant difference in reaction time in regular and irregular signals emerged after nine minutes of testing. For the first five minutes there was no significant difference between the tactile task of the groups. By the ninth minute, the tactile task of the irregular group was significantly poorer than that of the regular signal group.

The studies presented so far have dealt mainly with time estimation, having the subjects estimate a specific interval (e.g. 3 seconds). Are there any possible generalizations which can be made from these time estimation studies to the more intricate task of timing in regards to

---

the temporal organization of a sequence of movements? In 1973 Schmidt and his associates implied that the timing of component parts of a movement was mediated by the PFB received by the body. The two most prominent theories of timing concerning this inflow of proprioceptive feedback are the decay hypothesis and the input hypothesis of perceptual timing.

The decay hypothesis states that "the occurrence of a response at time \( t \) is assumed to generate a time varying stimulus trace and the stimulus trace at time \( t + \Delta t \) is the cue set to which the subject learns the response that is anticipatory to the environmental event by being initiated without a specific environmental cue."

Adams and Creamer\(^3\) claimed support for this hypothesis when they had subjects use a step tracking task with a manual lever control. The subject had to keep a pointer between two parallel lines which appeared on a revolving drum. Every two or four seconds the lines would disappear (no preview) and the subject would quickly have to move his pointer to the other side of the display where another set of parallel lines appeared (perceptual anticipation). The force necessary to keep the pointer in the correct position was variable, changing from one to four pounds. They predicted that the proprioceptive feedback generated in the first movement would be utilized to time the second response. It was also predicted that the greater the PFB, the more accurate would be the response. The results showed that the timing response was more accurate in the shorter intervals than with the longer intervals, but this evidence does not differentiate between the decay hypothesis or purely a cognitive

activity (counting), both of which predict poorer timing with longer intervals. However, increased amplitude did not show significant differences as evidenced by the non-significant findings of constant error, absolute error, and variable error. These findings were contrary to what was expected. Partial support for the decay hypothesis was provided when by using beneficial anticipations as a criterion score it was found that significant differences were found for the spring loading and duration conditions. This prompted some criticism from Schmid (1971). Perhaps the spring loading on the manually controlled lever offered a mechanical advantage, or provided proprioceptive cues which would have been evidence supporting the input hypothesis.

Christina\textsuperscript{34} recognized some deficiencies in the design of Adams and Creamer's 1962 study. The subject should be at rest between trials if the decay hypothesis is utilized to explain the subject's response. If the subject was not at rest between trials one could not be certain if the improved performance was due to an input of PFB during the interval or the decay of PFB during the interval. During Adams and Creamer's study, the subjects had to hold the spring tension lever in place which may have been a source of static continuous PFB used to time their response. Therefore, although the spring tension effects were significant, they do not differentiate between the decay and input hypotheses. Secondly, the PFB from spring loading was generated in the same limb that effected the response, and one cannot be sure that the spring system did not simply create a mechanically more favorable system for responding.

Christina\textsuperscript{35} decided to further test the decay hypothesis. He utilized a discrete task whereby the subject had to make a finger response following a two second interval and manipulated PFB in a prior movement with the left hand. The movement prior to the two second interval consisted of a 13 inch linear movement on a trackway with the left hand. A switch at the end of the movement started the two second interval. The PFB was manipulated by having no movement, unloaded movement, and loaded movement with the left hand. The results required to support the decay hypothesis would be to have the movement group superior to the non-movement group, and the loaded movement group superior to the movement group. Results were negative in all areas, which did not support the predictions of the decay hypothesis.

Quesada and Schmidt\textsuperscript{36} with the knowledge that Christina's subject's left arm movements were inconsistent, (consistency being a necessary variable for the support of the decay hypothesis), attempted to make the left arm movement more consistent by using a motor driven instrument. The subjects had their left arms moved through a 26 inch movement at a nearly consistent time of 1.42 seconds. At the end of the movement the subject's arm came to rest and he was to respond with a finger movement of the right hand following a two second delay. On the first day of the experiment, the subjects received KR on their 40 trials. The results supported the decay view. On the second day of the experiment, one week later, each subject was given 10 trials with KR and 20 trials without KR.

\textsuperscript{35}Robert W. Christina, op. cit., 125-133.

The rationale being that with withdrawal of KR, time estimation would deteriorate in the absence of PFB. Quesada and Schmidt claimed support for the decay view when the movement group, after withdrawal of KR, exhibited less overestimation of the time interval than did the non-movement group. There was less absolute error and less within subject variability for the movement group near the end of the 20 trials with KR withdrawal. This indicated that Christina may have failed to find support for the decay hypothesis in his experiment because of the inconsistency of the left arm movements.

Support for the decay hypothesis has been provided by Cummings and Santa Maria in 1972.37 Whereas a majority of studies designed to identify the role of PFB in timing motor responses have dealt with single limb movements with manipulations of amplitude and tension, Cummings and Santa Maria investigated this problem from a different angle. It was their thought that in skills requiring no preview, body rotation may be the most important source of PFB for timing motor responses (i.e. diving).

Sixty female volunteers were used to form two groups of thirty, a vestibular proprioception group (VP), and a non-vestibular proprioception group (NVP). The task for both groups was identical; they were to estimate a two second interval, following the appearance of a light, by depressing a right hand switch at the conclusion of the estimated two second interval. Each subject was given 40 trials with a 20 second inter-trial interval.

The starting position for the VP group was supine on a table 60 degrees from horizontal. They were then rotated to the horizontal. At

the end of the rotation they were to estimate a two second interval.

The NVP group's starting position was supine and in the horizontal plane. They were not rotated but were to estimate a two second interval following the appearance of a light stimulus.

Performance for both groups improved rapidly during the first ten trials. A Lindquist type I two-way analysis indicated that a significant improvement in performance, for the VP group, was obtained when trial scores were averaged over groups. A non-significant F ratio for interaction was obtained indicating that the trend in performance was similar for both groups.

The results of testing for group mean differences for algebraic error indicated that the performance of the VP group averaged over trials was significantly superior to the NVP group. The results of a two-way ANOVA indicated that no mean differences existed between the performance of the two groups as measured by variable error scores.

In 1969, Schmidt and Christina proposed and tested the input hypothesis of anticipatory timing. This hypothesis states that the subject uses the inflow of proprioceptive feedback from an earlier portion of a movement sequence to cue the timing of a later portion of the movement. In order for the information received through the input to be viable, it should be consistent from trial to trial.38

Grose39, with three different tasks, 1 - lifting a finger from a key, 2 - moving the hand two feet and pressing a key, and 3 - walking nine feet and kicking a barrier at the moment a moving pointer

became aligned with a stationary one, found that the larger the motor response, the smaller the directional error and an increase in movement consistency. Grose's explanation is that the larger movements created greater proprioceptive feedback. With the greater proprioceptive feedback, the subjects had stronger cues on which to base their timing response.

The role of proprioception and time estimation was investigated again in 1968 by Ellis, Schmidt, and Wade. They had subjects move a slide on a trackway while trying to estimate a two second interval. The interval began when the subject initiated his movement and was ended in exactly two seconds. Both increased amplitudes and increased loads were manipulated in order to increase proprioceptive feedback. Using absolute error, the withdrawal of knowledge of results resulted in a decrease in performance; however, the differences were not significant. Significant results were found only with the manipulation of amplitude. Load effects were not significant, creating findings nearly opposite to those of Adams and Creamer. However, Adams' and Creamer's results were based upon beneficial anticipations, not absolute error. Another possible explanation for the contrary results may be that Adams and Creamer did not tell the subjects the duration.

To determine the effects of various control system dynamics, Ellis used a similar task in 1969. In this study, Ellis manipulated acceleration cues by manipulating the inertia of the lever system, velocity


cues by manipulating the viscous resistance by an electromagnetic brake, and tension cues by manipulating the spring tension on the movement, and compared these conditions with no resistance control conditions. Utilizing absolute error, Ellis's results showed that the greater the PFB the greater the timing accuracy and response consistency, along with fewer trials to learn a skill. In addition, Ellis also had all the subjects spell 2, 3, and 4 letter words during their task. Timing accuracy increased as the number of letters in the words increased. This was attributed to the larger words creating a greater amount of PFB. When the words were withdrawn, the accuracy of the non-movement group regressed greatly, giving an indication that spelling gave them some cues for timing and when it was removed, they had no basis for estimating time. The movement group, however, still had the movement cues to rely on in the absence of spelling cues and experienced only slight decreases in accuracy. It seems probable from Ellis' work that subjects do not rely on such mechanisms as counting in everyday tasks requiring timing and that PFB is used in some way to improve timing.

Schmidt and Christina recognized that in all previous studies on timing, the PFB was manipulated by changing the dynamics of the control, and thereby changing the type of PFB may have also created a mechanically more favorable system for responding. They postulated that it would be a better test of PFB and its relation to timing if manipulations of PFB occurred in one limb and the response affected in

---

another limb. The PFB of the left arm was manipulated by having the subject either lift his finger, or create a small or large rotary movement. The initiation of the left arm movement started a target to which the subject had to respond to with his right hand when a moving arrow aligned with a stationary one. The target time was consistent at 1.50 seconds and beneficial anticipations were used as the criterion score. Results showed that although the small rotary movements led to significantly greater timing accuracy (analysis of algebraic error) than the finger movement, the large rotary movement did not result in significantly more accurate movements than did the small rotary movements. The findings here are not clear because the group with the greatest amount of PFB should have been the most accurate group. Later on it was discovered that the large movement was far more inconsistent than the small rotary movement and therefore, provided a poorer basis for timing than did the smaller movement. This is in direct support of the input hypothesis which states that consistency of PFB input is necessary from trial to trial. Christina's 1971 investigation provided further support for the results of Schmidt's and Christina's 1969 study. Christina (1971) used two groups and a rotating crank to produce high and low levels of PFB. Both groups operated the crank with their left hand and performed a timing task with their right hand. The result was that the high feedback group temporally anticipated with greater accuracy than the low feedback group. This supports the assumption that movement produced feedback generated by the left arm, provides the basis for the

anticipation and timing of the right hand response.

Using a similar apparatus as the one used by Schmidt and Christina\textsuperscript{44}, Christina\textsuperscript{45} investigated the effects of tension and movement PFB. With the left hand, the subjects had to make either a small (.5 inch) hand movement, a 13 inch linear movement of an unloaded slide, or a 13 inch movement of a loaded slide. The subject's initial movement started the target and the subject moved his left hand in one direction until he responded to the main task with the right hand. The groups with left arm movement performed the right arm timing task more consistently than the 0.5 inch movement group. The load effects were not significant. Also, the findings of no beneficial anticipation effects was contrary to earlier findings by Schmidt and Christina. The evidence brought forth by this experiment supports the view that proprioception serves as a mechanism underlying the temporal anticipation of motor responses.

Shultz\textsuperscript{46} (1974) attempted to duplicate Christina's\textsuperscript{47} (1970) study and attempted to demonstrate the superiority of either the decay or input theory of anticipatory timing. However, Shultz employed more sophisticated equipment than Christina did and exercised more control over independent variables. By utilizing a mechanical device, Shultz guaranteed that the amount of proprioceptive feedback would be consistent from trial to trial. Another unique aspect of his study was that Shultz researched

\textsuperscript{44}Richard A. Schmidt and Robert W. Christina, op. cit., 303-307.


\textsuperscript{47}Robert W. Christina, op. cit., 125-133.
the role of velocity cues in comparison to the more frequently studied force and position cues of proprioceptive feedback. The subjects were divided into three groups. Each subject received eight blocks of five trials. The control groups were used to determine how well the subjects could time in the absence of proprioceptive feedback. The subject moved a slide one centimeter to the right with his/her left hand. The subjects then depressed their right thumb at the same time a light appeared.

Two groups performed under decay conditions. They received proprioceptive feedback prior to the interval to be timed. Their left hand was passively moved along the trackway at either 13 or 40 centimeters per second. Their task was to depress a thumb switch with their right hand coincident with a light stimulus which was activated 1.5 seconds after the left arm movement was completed.

The input groups actively moved the slide down the trackway either 13 or 40 centimeters per second with their left hand and their right hand was used to depress a thumb switch coincident with the appearance of a light stimulus. Extrinsic knowledge of results was given after each trial for all subjects in each group. Auditory and visual cues were held to a minimum.

In his research, Shultz was concerned with the role of proprioceptive feedback in perceptual anticipation and in coincident response timing of a closed skill. The specific areas researched were: 1 - does a person use proprioceptive feedback, generated through rate of change of movement, to temporally anticipate a response coincident with an external stimulus? 2 - is accuracy of this timed response affected by the time of occurrence of proprioceptive feedback? 3 - does the amount of proprioceptive feedback affect the accuracy of a temporally anticipated coincident response?
is there a relationship between the ability to passively anticipate a coincident response and the ability to temporally anticipate a coincident response when proprioceptive cues are available?

The results of Shultz's study failed to demonstrate that the level or quantity of proprioceptive feedback provided for more accurate time estimation of an external event. He also failed to demonstrate that rate of change of movement (arm velocity) affects anticipatory timing ability when his two velocity groups did not differ from each other.

The non-significant comparison of his two groups receiving feedback prior to the interval to be timed, and his two groups receiving feedback during the interval to be timed demonstrated that the accuracy of a timed response is not affected by the time of occurrence of proprioceptive feedback. Therefore, Shultz's research yielded no superiority of either the input or decay theory of anticipatory timing. Additionally, his study indicated the proprioceptive feedback did not affect the accuracy or consistency of anticipatory timing. His proprioceptive feedback groups did not demonstrate a superiority to perceptually anticipate an external event over the groups not receiving proprioceptive feedback, in terms of the percent of beneficial anticipations.

At this point in the investigation of anticipatory timing, it seems evident that two specific areas should be further investigated:

1. The role of proprioceptive feedback in anticipatory timing under extended practice conditions.

2. To withdraw extrinsic knowledge of results during anticipatory timing tasks, so that only proprioceptive cues serve as a source of information for the subject.

As practice continues, performance undergoes changes. Under the
correct conditions the performance level will increase as practice continues. What are the reasons for these changes? Perhaps at different stages of practice, different abilities of the performer are being sampled. In 1954, Fleishman and Hemple used a complex coordination task to study this question. Each subject received 64 two minute trials. A one minute rest was given after each set of 16 trials.

Their study demonstrated that considerable changes occurred in the factor structure as practice continued. The first stage of practice trials, 1-5, was the most complex factorially. As practice continued it became less complex factorially. These results led the researchers to state "changes in factor loadings at different stages indicate that the quantitative pattern of abilities determining differences in goodness of performance changes with practice." These results indicate that individual differences in performance on the task after certain amounts of practice are likely to depend more on certain abilities and less on others than they did initially.

A year later, Fleishman and Hemple further investigated this same area of individual differences in performance due to a changing of critical abilities in later stages of practice. Factor analysis applied to eight different stages of practice on a visual discrimination task indicated considerable and systematic changes in the factor structure of the practice task as practice on the task was continued. Through the study it was demonstrated that the abilities contributing to individual

---


differences on the task were considerably changed and in a systematic and progressive way as practice continued. As in their research a year earlier, it was concluded that individual differences in performance on such tasks after certain amounts of practice are likely to depend more upon certain abilities and less on other abilities than they did initially.

In establishing the role of kinesthetic and spatial-visual abilities in perceptual motor learning, Fleishman and Rich in 1963 administered to each of forty males two ability measures, a standardized test of spatial orientation and a newly developed test of kinesthetic sensitivity. Each of the subjects was then given extended practice on a two handed coordination task. The authors were attempting to substantiate that in early learning periods, sensitivity to exteroceptive cues (visual) is critical, while later in the learning period sensitivity to proprioceptive cues (the feel of a movement) becomes the critical element. It was hypothesized that the subject with a superior sensitivity to proprioceptive cues would be more successful during the later stages of learning than would the other subjects. However, it does not necessitate that they would also excel during the beginning stages of the learning period. A secondary hypothesis was that the importance of the spatial-visual cues would diminish as practice continued.

When comparing results of the group which scored high on spatial measure ability, with the group that scored low on spatial measure ability, it was indicated that during early practice on the two handed coordination

task, the high group was initially better, but after 40 trials both groups were even. This shows that exteroceptive or spatial-visual sensitivity is critical in the early stages of learning.

When the results of time on target were compared for the group with high sensitivity for proprioceptive cues with the group for low sensitivity for proprioceptive cues, it was shown that as practice continues the two groups diverge with the high sensitivity group improving more rapidly than the low sensitivity group. During the early practice period there is no difference between these two groups. Later in the practice session, the difference between these two groups is significant.

According to the results of this study, it is evident that sensitivity to proprioceptive cues is more important later in perceptual motor learning, while sensitivity to exteroceptive (spatial-visual) cues is more critical earlier in learning. In effect, those subjects high in spatial ability have an advantage only in the earlier stage of learning. To achieve a higher score, finer motor adjustments are required. Those subjects who are especially sensitive to proprioceptive cues are able to make use of this information earlier in the practice period. They may be able to switch from a dependence on exteroceptive (spatial-visual) feedback to the more direct proprioceptive channels. The subjects who are limited in this sensitivity are more limited in the level of proficiency they can achieve at advanced levels of practice.

On the basis of Fleishman and his associate's work (1954, 1955, 1963), and in light of the remarks made by Tyldesley and Whiting (1974), that proprioceptive feedback may be an important component in learning a skill but may not occur until later phases of practice, this research
has employed extended practice sessions in an attempt to determine at what point in practice do proprioceptive abilities replace those abilities initially used for the performance of the task.

Investigating further into the phenomenon of motor learning without the aid of knowledge results, Wrisberg and Schmidt\textsuperscript{51}, 1975, had 24 right handed males move a slide 17 centimeters down a trackway to a stop. The subjects were then asked to repeat the movement without a stop. Each subject had 12 trials, before each trial the subject was allowed to move the slide to the stop. Knowledge of results was not administered for any of the trials.

Errors were computed on trials 1-6 and then on trials 7-12. Although variable error tended to decrease with practice, the difference was not significant. Constant errors which were initially negative on the first block (subjects undershooting the target) were reduced to nearly zero by the second block, which was significant. Therefore, the subjects were able to reduce their error over the course of practice without extrinsic knowledge of results.

The ability to improve without knowledge of results is attributed to what Adams terms the "perceptual trace"\textsuperscript{52}, and what Schmidt labels "expected sensory consequences." In both theories the subject is storing feedback about the correct movement whenever it is executed (when the subject moves the slide to the stop prior to each trial). As practice is continued, and as experience with the correct movement is


increased, a recognition memory of the correct location is formed making it easier to perform the correct movement. This is possible because the subject can match the response produced feedback with the recognition state which has been formed. Therefore, you have improvement taking place without knowledge of results.

Presently, the effect of proprioceptive feedback on anticipatory timing tasks is unclear. However, there appears to be some support that proprioception does act as a mediator for anticipatory timing tasks. Of the two theories used to explain anticipatory timing, it is unclear which of them best explains the timing phenomenon (Shultz, 1974, Christina, 1970). It has been indicated that if proprioception is to be a mediator of anticipatory timing that its inflow must be consistent from trial to trial. There is also some question as to whether the level of proprioceptive feedback is important in providing cues for anticipatory timing tasks.

This research will attempt to clarify the role of PFB in anticipatory timing through the use of extended practice sessions and withdrawal of extrinsic knowledge of results. It is predicted that this research will also support the input theory of anticipatory timing, and that the effect of different levels of PFB will be established.
CHAPTER III

PROCEDURES

The purpose of this chapter is to describe the methods used to investigate the effect of proprioception and extended practice sessions on a coincident timing task. The major sections of this chapter were: A. Instrumentation; B. Research Methodology; and C. Data Analysis.

Instrumentation

The apparatus consisted of a linear positioning device made up of two parallel steel drill rods, a double sleeve carriage and two end blocks. The steel drill rods were approximately three and one-half inches above a platform base. A sliding carriage moved freely on two anti-friction ball bushings. A light machine oil was used between the bushings to reduce friction.

The subject moved the carriage with his left hand from his left to his right by means of a small knob attached to the top of the carriage. The subject held a handswitch in his right hand and attempted to depress the switch coincident with an external stimulus event (buzzer sounding).

Performance was measured by a timing system which consisted of two digital stop clocks and a relay device which activated a buzzer 1.5 seconds after the beginning of the left to right linear movement. When the sliding carriage was in the starting position, it held two microswitches in the normally open position. One microswitch controlled
the digital stop clocks and the other microswitch controlled the relay device. When the carriage was moved, both clocks and the relay device were engaged. A free standing microswitch was placed either 18.5 or 60 centimeters down the trackway. By moving at a constant speed during the 1.5 second interval, the perceived velocities were considered to be related on the psychological scale of velocity. The group moving the shorter distance perceived the movement to be the midpoint between the faster movement and the control group. These values were determined by using the psychophysical evidence of Hoff53, 1971.

The free standing microswitch was positioned so that the sliding carriage would contact it as it passed. At the moment of contact, one of the clocks was stopped. At that moment the experimenter had to depress a switch to permanently stop the clock for that trial because once the carriage passed by the free standing microswitch, the switch was released and the clock started again.

Research Methodology

Selection and Assignment of Subjects. Seventy-five right handed subjects were used in this study. The subjects were chosen from the male physical education classes at Jamestown Community College, Jamestown, New York. Their ages ranged from 17-38 and previous athletic experience ranged from none to varsity level at Jamestown Community College. None of the subjects had previous experience with the

apparatus. The subjects were randomly assigned to one of three experimental groups.

**Administration of Proprioceptive Feedback.** The assumption that higher velocity movements would produce a different pattern of inflow and more discriminatory cues which would mediate the timing of a response to an external stimulus event was made for this research. Empirical support for this assumption was outlined in Shultz\(^5\)\(^4\), 1974.

In this investigation, groups one and two moved at constant velocities of 12.33 and 40.00 centimeters per second respectively. It was predicted that group two would have more discriminatory cues to time since the level of proprioception was greater than group one. Group three was a control group. Precautions taken to eliminate KR and PFB in group three included: no left arm movement, blindfolds to prohibit sight references, no body movements were permitted after the subject was positioned for testing (hand and foot tapping, etc.). The subject sat facing the apparatus and the experimenter. The subject was seated in a straight back chair, both feet touching the floor. His left hand was on the sliding carriage directly in front of him and his right hand was resting on the table in front of him, holding a thumb switch.

A comparison of timing performance by the control and experimental groups would allow some insight into the role of PFB in timing.

**Measurement of Performance.** Performance was based on how accurately and consistently the subject learned a 1.5 second interval. The subjects were to move their left hand at a velocity of either 12.33

centimeters per second, or 40.00 centimeters per second. The subjects were informed if their velocity was "too slow" or "too fast". The group moving the carriage correctly at a velocity of 12.33 centimeters per second would move 18.5 centimeters in 1.5 seconds, and the 40.00 centimeters per second group would move 60.00 centimeters in 1.5 seconds. Because of imperfections in the equipment an error tolerance range about the desired velocity was established. A velocity which brought the left hand movement the desired distance (18.5 or 40.00 centimeters) in 1.42 seconds to 1.58 seconds was considered a correct response.

Allowing for the discrepancy within the interval timer, an error tolerance was established for the right hand coincident timing task. Acceptable right hand timing responses were between 1.49 and 1.51 seconds.

The statistical tools of constant error (CE), variable error (VE), and absolute error (AE), were used to interpret performance results. Absolute error was utilized only to compare it to other studies using AE. Absolute error is dependent upon CE and VE and it can be predicted from them. "The use of all three error statistics should not be necessary, and the procedure of performing analyses of variance on each statistic in the hope that something will be significant is a statistical blunder." 55 Actually absolute error is uninterpretable except as a weighted sum of CE and VE, and is very strongly

correlated with both of these error scores. Most all distributions can be described by the independent variables of CE and VE, therefore, it is a valid procedure to use these two statistics jointly.

Administration of KR and Schedules of Practice. Each subject received fifty trials per day for four successive days. Following each set of five trials there was a twenty second inter-response time. Qualitative KR was given for trials 1-24 via the buzzer (intrinsic) and the experimenter (extrinsic). Regarding the velocity of the left hand movement, the subject was told if his movement was too fast, too slow, or correct. The sounding of the buzzer at exactly 1.5 seconds after the initiation of the left hand movement also aided the subject in determining if his timing task was executed too early or too late. Following the twenty-fourth trial, all extrinsic KR was removed except that for the velocity of the left hand movement. This facet of KR was continued for all trials. For groups one and two, administration of KR was the same. In group three there was no left hand movement. Therefore, for trials 1-24, they received KR concerning the timing task and they heard the buzzer, while for trials 25-50, they received no KR at all.

Data Analysis

The basic design of this study was four factor experiment (treatment X day X blocks X KR manipulation) with repetition on three factors (Weiner, 1971, pp. 359-371) or a split-plot factorial

(SPF -3.452) design (Kirk, 1968, pp. 308-311). The factors of days, blocks and KR manipulations were within -S variables and the three treatment conditions (different velocity conditions) were the between -S variable. Analyses of constant errors, variable errors and absolute errors were included. The interpretation of results was primarily concerned with constant and variable errors due to the criticism of absolute errors by Schutz and Roy57, 1973. However, absolute error was included so that comparisons to previous research which employed this "devil in disguise" could be made.

Since the data which was generated by this study involved "learning curves," it was anticipated that there would be a failure in meeting the assumption of homogeneity of covariance. Due to the limitation of the computer facilities at SUC at Brockport (IBM 1130) and because of the criticalness of the assumption for repeated measures designs (Kirk, 1968 p. 248), the Geisson-Greenhouse conservative F test (Kirk, 1968, p. 262) was used.

Computer support for this investigation was provided by the Academic Computing Center, State University of New York, College at Brockport.

CHAPTER IV
RESULTS AND DISCUSSION

This study was concerned with perceptual anticipation in a coincident timing task and the role of PFB and extended practice sessions on timing performance. The extended practice was also used to determine the viability of a two stage theory of input timing. The most important distinction of this investigation is that it allowed the investigator to look at the effects of manipulating PFB and KR on a task over a longer period of time (four days, 200 trials) than previously conducted research in this area.

The primary purpose of this study was to compare the anticipatory timing ability of three different groups performing under input conditions of peripheral timing. Each group received a varying level of PFB (low, high, zero) in order to determine the effects of different amounts of PFB on timing performance.

The analysis of this study utilized three different statistical factors. Constant error, a measure of response bias was used to determine if the subjects were early or late in responding to an external event. Variable error was used to analyze the consistency of responding within each individual. Also, absolute error was used to indicate the average absolute deviation about a target. Its inclusion in this study was solely to compare it to other studies that employed only absolute error. Tests for homogeneity of covariance were not
performed, therefore, the conservative degree of freedom procedure was utilized.\textsuperscript{58}

**Constant Error**

**Results.** An analysis of constant error indicated that the among subjects groups factor was significant at the .05 level of risk with an F-ratio of 3.65. This indicated that one of the three group's means differed significantly from at least one of the other groups in response bias (see table #1). The means were: group one (slow velocity) 0.025, group two (fast velocity) 0.013, and group three (control group, no velocity) -0.036. All constant error values are in seconds and represent a deviation score from the ideal or perfect score of 1.50 seconds. A Neuman-Keuls post hoc analysis indicated that the two movement groups differed from the control group but not from each other.

Within subjects a repeated measures analysis for response bias revealed that the two main effects of blocks was significant with an F-ratio of 13.05 (see table #3). The means for blocks one, two, three, four, and five were: -0.029, 0.005, 0.010, 0.007, and .009 respectively. The first order interaction was also significant therefore a test of the simple main effects were performed on blocks by groups.\textsuperscript{59}


Table #1
Repeated Measures Analysis of Constant Errors in Anticipatory Timing

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>ss</th>
<th>ms</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>2</td>
<td>2.126112</td>
<td>1.063056</td>
<td>3.647*</td>
</tr>
<tr>
<td>S</td>
<td>72</td>
<td>20.987015</td>
<td>0.291486</td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>0.647451</td>
<td>0.161863</td>
<td>13.050*</td>
</tr>
<tr>
<td>BG</td>
<td>8</td>
<td>0.807321</td>
<td>0.100915</td>
<td>8.136*</td>
</tr>
<tr>
<td>BS</td>
<td>288</td>
<td>3.572115</td>
<td>0.012403</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>1</td>
<td>2.190457</td>
<td>2.190457</td>
<td>47.715*</td>
</tr>
<tr>
<td>KG</td>
<td>2</td>
<td>0.860812</td>
<td>0.430406</td>
<td>9.376*</td>
</tr>
<tr>
<td>KS</td>
<td>72</td>
<td>3.305276</td>
<td>0.045907</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>1.763179</td>
<td>0.587726</td>
<td>10.386*</td>
</tr>
<tr>
<td>DG</td>
<td>6</td>
<td>2.065388</td>
<td>0.344231</td>
<td>6.083*</td>
</tr>
<tr>
<td>DS</td>
<td>216</td>
<td>12.223183</td>
<td>0.056589</td>
<td></td>
</tr>
<tr>
<td>BK</td>
<td>4</td>
<td>0.091372</td>
<td>0.022843</td>
<td>1.688</td>
</tr>
<tr>
<td>BKG</td>
<td>8</td>
<td>0.105745</td>
<td>0.013218</td>
<td>0.977</td>
</tr>
<tr>
<td>BKS</td>
<td>288</td>
<td>3.897506</td>
<td>0.013533</td>
<td></td>
</tr>
<tr>
<td>BD</td>
<td>12</td>
<td>0.200351</td>
<td>0.016696</td>
<td>1.722</td>
</tr>
<tr>
<td>BDG</td>
<td>24</td>
<td>0.568070</td>
<td>0.023670</td>
<td>2.442</td>
</tr>
<tr>
<td>BDS</td>
<td>864</td>
<td>8.375816</td>
<td>0.009694</td>
<td></td>
</tr>
<tr>
<td>KD</td>
<td>3</td>
<td>0.048939</td>
<td>0.016313</td>
<td>0.679</td>
</tr>
<tr>
<td>KDG</td>
<td>6</td>
<td>0.445220</td>
<td>0.074203</td>
<td>3.089</td>
</tr>
<tr>
<td>KDS</td>
<td>216</td>
<td>5.189348</td>
<td>0.024025</td>
<td></td>
</tr>
<tr>
<td>BKD</td>
<td>12</td>
<td>0.223018</td>
<td>0.185850</td>
<td>1.983</td>
</tr>
<tr>
<td>BKDG</td>
<td>24</td>
<td>0.403867</td>
<td>0.016828</td>
<td>1.796</td>
</tr>
<tr>
<td>BKDS</td>
<td>864</td>
<td>0.096312</td>
<td>0.009371</td>
<td></td>
</tr>
</tbody>
</table>

*Exceeds critical F value for conservative degrees of freedom

Among Subjects
G=Group
S=Subject

Within Subjects
B=Blocks
K=Knowledge of Results
D=Days
The test indicated that at least two groups differed from one another at block one, but none of the groups differed from each other at blocks 2, 3, 4, or 5.

Table #2

Simple Main Effects of Groups

at each level of Factor B (blocks)

<table>
<thead>
<tr>
<th>Source</th>
<th>ss</th>
<th>df</th>
<th>ms</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>G at b₁</td>
<td>1.68</td>
<td>2</td>
<td>0.84</td>
<td>12.35*</td>
</tr>
<tr>
<td>G at b₂</td>
<td>0.32</td>
<td>2</td>
<td>0.16</td>
<td>2.35</td>
</tr>
<tr>
<td>G at b₃</td>
<td>0.30</td>
<td>2</td>
<td>0.15</td>
<td>2.21</td>
</tr>
<tr>
<td>G at b₄</td>
<td>0.30</td>
<td>2</td>
<td>0.15</td>
<td>2.21</td>
</tr>
<tr>
<td>G at b₅</td>
<td>0.31</td>
<td>2</td>
<td>0.15</td>
<td>2.21</td>
</tr>
<tr>
<td>Pooled error</td>
<td>24.56</td>
<td>360</td>
<td>0.068</td>
<td></td>
</tr>
</tbody>
</table>

Critical F value for 2, 360= 3.00

*Exceeds critical F value for conservative degrees of freedom

A Neuman-Keuls post hoc analysis of the simple main effect implied that the significant findings were due to the under estimation of the control group in block one only. All of the other simple main effects were nonsignificant at the .05 level.

An analysis of variance for response bias for the knowledge of results factor proved significant (F-ratio 47.72) at the 0.05 level of risk. However, a two way interaction of knowledge of results by groups was significant, F-ratio 9.38, so a test of simple main effects was performed. The test indicated that under the KR condition at least two
groups were significantly different from one another. Under the NKR condition there were no differences among the three groups (see table #3).

Table #3
Simple Main Effects for Groups
at each level of Factor K

<table>
<thead>
<tr>
<th>Source</th>
<th>ss</th>
<th>df</th>
<th>ms</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>G at K₁</td>
<td>2.65</td>
<td>2</td>
<td>1.32</td>
<td>7.82*</td>
</tr>
<tr>
<td>G at K₂</td>
<td>0.33</td>
<td>2</td>
<td>0.16</td>
<td>0.95</td>
</tr>
<tr>
<td>Pooled error</td>
<td>24.29</td>
<td>144</td>
<td>0.169</td>
<td></td>
</tr>
</tbody>
</table>

Critical F Value 3.08

*Exceeds critical F value for conservative degrees of freedom

The Neuman-Keuls post hoc analysis indicated that group three (control) significantly differed from both the fast and slow groups. Group three continually underestimated the time interval. When comparing the three groups under conditions of KR withdrawal each of the three groups exhibited positive response bias.

An analysis of variance for the main effect of days was significant at the .05 level, F-ratio 10.39. The means for the four days were: day one 0.041, day two 0.010, day three 0.010, and day four 0.023. However, the two way interaction of days by groups was significant and necessitated a test of the simple main effects. The test of the simple main effects indicated significant differences on both day
one and day two. At least two of the groups differed from each other on both of these days. Days three and four showed no difference among groups (see table #4).

Table #4
Simple Main Effect of Groups
at each level of Factor D (days)

<table>
<thead>
<tr>
<th>Source</th>
<th>ss</th>
<th>df</th>
<th>ms</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>G at d1</td>
<td>3.16</td>
<td>2</td>
<td>1.58</td>
<td>13.74*</td>
</tr>
<tr>
<td>G at d2</td>
<td>0.92</td>
<td>2</td>
<td>0.46</td>
<td>4.00*</td>
</tr>
<tr>
<td>G at d3</td>
<td>0.06</td>
<td>2</td>
<td>0.03</td>
<td>.26</td>
</tr>
<tr>
<td>G at d4</td>
<td>0.03</td>
<td>2</td>
<td>0.01</td>
<td>.09</td>
</tr>
<tr>
<td>Pooled error</td>
<td>33.21</td>
<td>288</td>
<td>0.12</td>
<td></td>
</tr>
</tbody>
</table>

Critical F-Value 3.04
*Exceeds critical F value for conservative degrees of freedom

The Neuman-Keuls post hoc analysis indicated that the control group significantly differed (underestimated) from groups one and two on day one. On day two the slow group differed from the control group. The slow group was less accurate than the control group. There were no other differences among groups on days three and four.

The second, third and fourth order interaction factors failed to be significant at the .05 level utilizing conservative degrees of freedom.

Discussion. The results of this investigation partially support
those of Christina (1970). Christina manipulated PFB by having a .5 inch movement, a 13 inch movement, or a 13 inch movement with a 3.4 pound load. He found significant performance differences between the groups with a movement and the group without a movement. However, Christina's investigation demonstrated no significant difference between groups receiving PFB. The present study duplicated this finding, however, the mean errors were ordered in the appropriate fashion suggesting that increasing levels of PFB up to those investigated in this study tended to produce more favorable responding.

The lack of significance between Christina's two PFB groups may well be attributed to the fact that input of PFB for his high PFB groups was not kept consistent from trial to trial. In the present study with significance between the high and low PFB groups failing by so narrow a margin, the author feels that with a few more trials or a few more subjects, significance may have been demonstrated between the two PFB groups. It is also possible that the difference between the varying levels of PFB for the low and high PFB groups was not sufficient enough to produce discriminable cues.

Ellis, Schmidt and Wade, (1968) also demonstrated that their


movement groups were more accurate in their timing task than their nonmovement group. Here again the PFB groups did not differ among themselves. Two explanations of these results exist. The first is that Ellis et al used an input pattern which was too complex to provide discernible cues for timing. Secondly, the feedback groups operated under more favorable conditions for responding. In the present study the method of PFB input was kept simple, (rate of change of movement), and all groups operated under the same mechanical conditions for responding to PFB.

The present study also contradicts the results of Schmidt and Christina, (1969).62 As in previous studies of coincident timing, they could not demonstrate any significant difference between varying levels of PFB and timing accuracy. The lack of consistent PFB for each trial was at least partially responsible for their non-significant results.

Regarding performance of groups over blocks of trials, the present study supported the work of Shultz, 197463, but was contradictory of the results obtained by Christina, 1970.64 Christina's

---


64 R. W. Christina, op. cit., 125-133.
investigation had a time interval of two seconds as opposed to this investigation's interval of 1.5 seconds. His subjects demonstrated a negative bias among groups receiving PFB while the present investigation demonstrated that the groups receiving PFB tended to lag the external event. Cummings and Santa Maria (1972) and Quesada and Schmidt (1970) tested the decay hypothesis and utilized a mechanical device to insure a consistent level of PFB for each trial. In both investigations the experimental groups underestimated the external event. Ellis', 1969 results of a test of the input hypothesis indicated an overestimation of the external event by his subjects. Thus the overestimation of the PFB groups in this investigation are in accordance with other studies of the input hypothesis.

The reason for blocks by groups being a significant factor in this investigation was the control group's gross underestimation of the external event in block one only. By the second block of trials the amount of underestimation had decreased significantly. The unfamiliarity of the task combined with the control conditions of group three is a


possible explanation of the vast discrepancy of group three in block one. The test of the simple main effects of blocks by groups indicated that the fast group differed from both of the other two groups. In addition, the slow group also differed from the control group.

In block one the most accurate group was the slow (low PFB) group, followed by the fast (high PFB) group, and lastly the control (zero PFB) group. Although both movement groups differed from each other it was expected that the fast group would be more accurate than the slow group since it was receiving a greater amount of PFB. Blocks 2-5 did partially support the theory of increased accuracy with increased levels of PFB. In each of these blocks, the fast group was more accurate than the slow group although the differences were not significant. A possible explanation of why group two became more accurate than group one in blocks 2-5 lies in the extended practice theory of this research. The results indicate that initially (block one, first 5 trials) the subjects had slight difficulty coping with the larger amounts of PFB. As practice continued the subjects could more skillfully make use of the PFB.

Unlike the 1970 results of Quesada and Schmidt where the feedback groups overestimated the interval during a test of Adams' decay hypothesis, in this study, the subjects receiving KR exhibited a negative response bias, and significantly differed from the NKR group, \( F = 47.72 \). However, neither group was more accurate. The KR group underestimated the interval by .27 and the NKR group overestimated by .28. Possibly the difference between Quesada and Schmidt's findings, and the findings of this study is that Quesada and Schmidt used
operative time estimation under decay conditions, and this study used a reproductive task under input conditions.

Since the main effect of KR was significant, a test of the simple main effects was administered. The results indicated that the slow group and the fast group differed from the control group. The two PFB groups did not differ from each other. This information indicates that PFB combined with KR seems to produce the most accurate results. Upon withdrawal of KR there were no significant differences in accuracy among the three groups. Because of the simplicity of the task involved, by the time KR was withdrawn the task may have already been learned and a perceptual trace established. Performance under these conditions may remain the same or even improve.68 The control group demonstrated a shift from underestimation with KR to overestimation when KR was withdrawn, with a net result of greater accuracy for the control group without KR than with KR. Both of the PFB groups had a tendency to overestimate the interval with KR removed which resulted in a performance decrement when compared to their responses with KR. These results of a positive bias when KR is withdrawn coincide with the results of K. M. Newell, 197469 when he found that KR withdrawal resulted in a tendency for subjects to overestimate a time interval as an inverse function of the number of prior KR acquisition trials.


The main effect of days was also significant ($F = 10.32$) and necessitated a test of the simple main effects of days by groups. This factor was also significant $F = 7.23$. The test for simple main effect of days by groups indicated that on day one the slow group and the fast group significantly differed from the control group, but the fast group and the slow group did not differ from each other. This is evidence that groups receiving PFB were more accurate than groups not receiving PFB, and is direct support for the input theory of timing. The accuracy of the two PFB groups can be attributed to Adams' closed loop theory of motor learning\textsuperscript{70} and the formation of a perceptual trace. The perceptual trace is what the subject uses as a reference point to adjust his next movement on the basis of the KR he receives. The PFB the subject receives from each ongoing movement is compared to the perceptual trace. Each of the two movement groups in this investigation had ample time during their task to compare their movement with their perceptual trace and to make adjustments in their performance. The second day of the experiment revealed no difference between the fast groups and the control group but a difference did exist between the slow group and the control group with the control group being more accurate than the low PFB group. Days three and four indicated no differences between any of the groups. What happened between day one and day two to account for the differences between the

\textsuperscript{70}Jack A. Adams, op. cit., 111-149.
control group and group number two, and to allow the control group
to time as accurately as the fast group? Perhaps because of the
relative simplicity of the task the control group, by the end of
day two (100 trials), had learned the task as well as the fast group
did. Following day two, all the groups performed the same. It is
possible that after day two the responses of the groups were no longer
controlled by a closed loop process of input timing, but relied on an
open loop concept of central representation to order their movement.71

The second and third order interactions of the day factor were
not significant.

Variable Error

Results. An analysis of the consistency of responding within an
individual indicated that the main effect of groups was significant
at the .05 level of risk with an F-ratio of 10.20 (see table #5).
The means for the main effect of groups were: group one 0.037, group

71 D. A. Tyldesley and H. T. A. Whiting, "Timing as an Output
Characteristic," The British Society of Sports Psychology. Ed J.
three 0.050. A Neuman-Keuls post hoc analysis indicated that all three groups differed significantly from each other.

Table #5
Repeated Measures Analysis of Variable Errors in Anticipatory Timing

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>ss</th>
<th>ms</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>2</td>
<td>0.408234</td>
<td>0.204117</td>
<td>10.150*</td>
</tr>
<tr>
<td>S</td>
<td>72</td>
<td>1.447908</td>
<td>0.020110</td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>0.122412</td>
<td>0.030603</td>
<td>17.319*</td>
</tr>
<tr>
<td>BG</td>
<td>8</td>
<td>0.018247</td>
<td>0.002281</td>
<td>1.291</td>
</tr>
<tr>
<td>BS</td>
<td>88</td>
<td>0.508973</td>
<td>0.001767</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>1</td>
<td>0.008223</td>
<td>0.008223</td>
<td>3.775*</td>
</tr>
<tr>
<td>KG</td>
<td>2</td>
<td>0.006141</td>
<td>0.003071</td>
<td>1.410</td>
</tr>
<tr>
<td>KS</td>
<td>72</td>
<td>0.156819</td>
<td>0.002178</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>0.157675</td>
<td>0.052558</td>
<td>14.384*</td>
</tr>
<tr>
<td>DG</td>
<td>6</td>
<td>0.027295</td>
<td>0.004549</td>
<td>1.245</td>
</tr>
<tr>
<td>DS</td>
<td>216</td>
<td>0.789225</td>
<td>0.003654</td>
<td></td>
</tr>
<tr>
<td>BK</td>
<td>4</td>
<td>0.110562</td>
<td>0.027638</td>
<td>17.889*</td>
</tr>
<tr>
<td>BKG</td>
<td>8</td>
<td>0.043170</td>
<td>0.005396</td>
<td>3.493</td>
</tr>
<tr>
<td>BDS</td>
<td>288</td>
<td>0.444879</td>
<td>0.001546</td>
<td></td>
</tr>
<tr>
<td>BD</td>
<td>12</td>
<td>0.084436</td>
<td>0.007037</td>
<td>4.001*</td>
</tr>
<tr>
<td>BDG</td>
<td>24</td>
<td>0.047867</td>
<td>0.001994</td>
<td>1.134</td>
</tr>
<tr>
<td>BDS</td>
<td>864</td>
<td>1.519887</td>
<td>0.001759</td>
<td></td>
</tr>
<tr>
<td>KD</td>
<td>3</td>
<td>0.088630</td>
<td>0.011071</td>
<td>5.263*</td>
</tr>
<tr>
<td>KDG</td>
<td>6</td>
<td>0.007956</td>
<td>0.001326</td>
<td>0.634</td>
</tr>
<tr>
<td>KDS</td>
<td>216</td>
<td>0.451870</td>
<td>0.002226</td>
<td></td>
</tr>
<tr>
<td>BKD</td>
<td>12</td>
<td>0.088630</td>
<td>0.007386</td>
<td>3.956</td>
</tr>
<tr>
<td>BKDG</td>
<td>24</td>
<td>0.053418</td>
<td>0.002226</td>
<td>1.192</td>
</tr>
<tr>
<td>BKDS</td>
<td>264</td>
<td>1.613018</td>
<td>0.001867</td>
<td></td>
</tr>
</tbody>
</table>

*Exceeds critical F value for conservative degrees of freedom

The main effect of blocks was also a significant factor at the .05 level (F-ratio 17.32). This indicated that at least one of the group's means differed significantly from the other. There were no
significant findings in the first order interaction of blocks by groups.

A repeated measures analysis of the four day variable error indicated a nonsignificant finding for the main effect of knowledge of results, F-ratio 3.78 (means for the KR factor are 0.038 with KR and 0.034 without KR).

Days was a significant main effect with an F-ratio of 14.38. A Neuman-Keuls post hoc analysis indicated that day one differed from the following three days of practice. This is evidence that the significant difference of days is due to the first day of trials. After the first day the differences were not significant. There were no significant results of the first order interaction of days by groups.

The first order interaction of BK, BD, and KD were all significant. The second order interaction of BKD just failed to be significant at the .05 level using conservative degrees of freedom. The significant results of BK were due to the participants performance in block one. Under conditions of KR block one was significantly less consistent with any of the other blocks. There were no differences under the KR withdrawal condition. Concerning the BD factor here again the significant result was due to the inconsistent responding found in block one on day one. There were no other differences found on days two through four. Knowledge of results by days showed that under KR conditions the responses on day one were significantly less consistent than the responses on days two, three, and four. Under conditions of KR withdrawal the responses of day one again were significantly different than the responses recorded on days two, three and four. However, the
responses of day one under KR withdrawal were more consistent than responses on day one under KR. The performance on days two, three, and four were almost identical under conditions of KR and NKR.

Discussion. The findings of this study that PFB contributed to more consistent responding is similar to Quesada's 1970 test of the decay hypothesis. However, it disagrees with the results of Christina (1970), and Cummings and Santa Maria (1972). In the present study both PFB groups significantly differed from each other and from the control group. This is attributable to the extended practice factor incorporated in this investigation. This factor allowed the participants more time to utilize information gained through PFB (via more trials) and to apply that information in their subsequent trials.

The subject's performance on blocks of trials indicated a significant difference between block one and the other blocks. The majority of evidence in this area, however, tends to support the opposite. An exception to this was when in 1974, Shultz found significant simple

---


effects between his three velocity groups during blocks three and four. In the present study no significance of blocks was demonstrated after the first block of trials. This result may be attributed to the warm-up decrement factor. After a period of rest, performance may be somewhat depressed for anywhere from two to five trials.\textsuperscript{76} In the present study the blocks were comprised of five trials. It is therefore possible that each block of trials was performed anywhere from 40\% to 100\% under the influence of the warm-up decrement factor.

Knowledge of results was not significant. It is possible that the subjects did not have enough time between trials to assimilate the KR and respond accordingly. The subject had at least 10 seconds after he received his KR before he began his next trial. Although this factor was not significant the groups receiving KR were more consistent than the groups not receiving KR (KR mean 0.034, NKR mean 0.038). Withdrawal of KR did not effect performance consistency. Each group was administered fifty trials per session. The first twenty-four trials were accompanied by KR while trials twenty-five through fifty were conducted under KR withdrawal.

In explaining the non-significant results of the KR factor, Grose in 1967\textsuperscript{77} provided evidence that in a coincident timing task involving


receptor anticipation subjects were able to learn to anticipate and time their responses without extrinsic knowledge of results. K. M. Newell found similar results when using a short, fast timing linear movement, his subjects demonstrated sustained performance with low error after KR was withdrawn. In the present study consistency of response was made possible by the perceptual trace established during the first twenty-five trials, twenty-four of which were accompanied by intrinsic KR in the form of a buzzer. The formation of the perceptual trace during the first twenty-five trials was the factor responsible for allowing the participants to respond consistently for the second twenty-five trials under KR withdrawal.

An alternative explanation for the consistency of performance following the withdrawal of KR may be the formation of a motor program. The motor program theory consists of two stages. The first stage is that time during which the performers are dependent upon PFB to order their movements. After considerable practice time the sequencing and timing of skills become controlled by a central motor program of the central nervous system rather than by information gained through PFB. For these reasons there were no significant differences in response consistency between the KR and NKR groups. According to


Adams', 1971, performance may be hindered if there is any activity during the post KR delay interval. It is possible that this factor affected the subject's performance in this study. During each post KR interval the subject returned the sliding carriage to the starting position for the next trial. If a stable perceptual trace has not been established, the activities during the post KR delay interval tend to deteriorate the existing trace. Perhaps this activity during the early trials of KR may have had a disruptive effect. This may have created some inconsistency. Coupled with this the absence of extrinsic KR in trials 25-50 may have resulted in consistent but inaccurate responses. Thus the net effect was no differences between KR and NKR.

Using conservative degrees of freedom the second order interaction of BKD was nonsignificant. Therefore, the discussion can only entail the interactions of BK, BD, and KD. Under KR conditions of variable error blocks by knowledge of results was significant due to the inconsistent responses in block one only. There were no differences in blocks two through five. After withdrawing KR none of the blocks (2-5) were significantly different. Blocks one and two indicated a drop in the amount of overestimation and an increased consistency from the KR condition to the NKR condition. A viable explanation for this is provided by the perceptual trace theory. Blocks one and two under KR represent the first ten or fifty trials, and may very well be influenced by warm-up decrement, hence the poor consistency. However, blocks one

and two of the NKR condition are trials twenty-six through thirty-five of fifty trials. It is possible that after the first twenty-five trials a perceptual trace had been established, therefore, more consistent responses resulted. Blocks three, four, and five, under KR were more consistent than blocks one and two. This was a logical result. The warm-up decrement factor has waned since the first two blocks and the perceptual trace is beginning to affect performance in blocks three, four, and five.

Due to the inconsistency of responding of the subjects in block one of day one, blocks by days was a significant factor. Blocks 2-5 on day one did not differ from one another. Days 2-4 showed no difference between any of the five blocks.

Responses for day one with KR were significantly less consistent than the responses for days 2-4. There were no differences for days 2-4 with KR. KR withdrawal resulted in day one being significantly different from days 2-4. After day one, there were no differences between any of the groups. This is possibly due to the fact that an adequate perceptual trace was not developed on day one but was developed in subsequent days.

Absolute Error. Absolute error was used to indicate the average absolute deviation about a target interval. Its inclusion in this study is solely to compare it to other studies that employed only absolute error (see table #6).

An analysis of variance of absolute error revealed that the main effect of groups was significant (F-ratio 9.65) at the .05 level of risk. The means for the groups were: group one 0.105, group two 0.073, and group three 0.142. A Neuman-Keuls post hoc analysis im-
plied that group two (high PFB) differed from each of the other two
groups, however, there were no significant findings between groups
one and three.

A repeated measures analysis of absolute error for the main
effects of blocks was significant at the .05 level of risk with an
F-ratio of 5.37. The absolute error means for blocks are: block
one 0.119, block two 0.108, block three 0.103, block four 0.099,
and block five 0.104. There was no significant first order inter­
action of blocks by groups or blocks by subjects. Blocks by KR
was significant F-ratio 15.55.

The main effect of KR was significant as we indicated by an
analysis of variance for absolute error, (F-ratio 8.72). The abso­
lute error means for KR were KR 0.099 and NKR 0.115. There were
no significant findings in any of the two way interactions for simple
main effects.

Analysis of variance for absolute error over days was significant
(F-ratio 9.10). There were no significant findings of any simple main
effects of days by groups or days by subjects. Knowledge of results
by days was significant, F-ratio 5.20. All other interactions were not significant.

Table #6
Repeated Measures Analysis
of Absolute Errors in Anticipatory Timing

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>ss</th>
<th>ms</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>2</td>
<td>2.367401</td>
<td>1.183700</td>
<td>9.654*</td>
</tr>
<tr>
<td>S</td>
<td>72</td>
<td>8.827888</td>
<td>0.122610</td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>0.142744</td>
<td>0.034686</td>
<td>5.369*</td>
</tr>
<tr>
<td>BG</td>
<td>8</td>
<td>0.067324</td>
<td>0.007166</td>
<td>1.078</td>
</tr>
<tr>
<td>BS</td>
<td>288</td>
<td>1.914194</td>
<td>0.006647</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>1</td>
<td>0.202147</td>
<td>0.202147</td>
<td>8.715*</td>
</tr>
<tr>
<td>KG</td>
<td>2</td>
<td>0.114042</td>
<td>0.057021</td>
<td>2.458</td>
</tr>
<tr>
<td>KS</td>
<td>72</td>
<td>1.670104</td>
<td>0.023196</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>1.090882</td>
<td>0.363627</td>
<td>9.109*</td>
</tr>
<tr>
<td>DG</td>
<td>6</td>
<td>0.395533</td>
<td>0.066089</td>
<td>1.656</td>
</tr>
<tr>
<td>DS</td>
<td>216</td>
<td>8.622502</td>
<td>0.039919</td>
<td></td>
</tr>
<tr>
<td>BK</td>
<td>4</td>
<td>0.414757</td>
<td>0.103689</td>
<td>15.553*</td>
</tr>
<tr>
<td>BKG</td>
<td>8</td>
<td>0.124572</td>
<td>0.015572</td>
<td>2.336</td>
</tr>
<tr>
<td>BKS</td>
<td>288</td>
<td>1.920020</td>
<td>0.006667</td>
<td></td>
</tr>
<tr>
<td>BD</td>
<td>12</td>
<td>0.303109</td>
<td>0.025259</td>
<td>3.648</td>
</tr>
<tr>
<td>BDG</td>
<td>24</td>
<td>0.288445</td>
<td>0.012019</td>
<td>1.736</td>
</tr>
<tr>
<td>BDS</td>
<td>864</td>
<td>5.982141</td>
<td>0.006924</td>
<td></td>
</tr>
<tr>
<td>KD</td>
<td>3</td>
<td>0.261699</td>
<td>0.087233</td>
<td>5.179*</td>
</tr>
<tr>
<td>KDG</td>
<td>6</td>
<td>0.284757</td>
<td>0.047460</td>
<td>2.818</td>
</tr>
<tr>
<td>KDS</td>
<td>216</td>
<td>3.637957</td>
<td>0.016842</td>
<td></td>
</tr>
<tr>
<td>BKD</td>
<td>12</td>
<td>0.145032</td>
<td>0.012086</td>
<td>2.047</td>
</tr>
<tr>
<td>BKDG</td>
<td>24</td>
<td>0.161895</td>
<td>0.006746</td>
<td>1.142</td>
</tr>
<tr>
<td>BKDS</td>
<td>864</td>
<td>5.102107</td>
<td>0.005905</td>
<td></td>
</tr>
</tbody>
</table>

*Exceeds critical F value for conservative degrees of freedom

Discussion. The statistical method of absolute error was employed only to compare the present study's absolute error findings with those studies that employed absolute error as their only measuring device.
Christina's results in 1971 were both supported and contradicted by this investigation. Support for Christina was shown when this author found significant differences between the control groups and the high level PFB group on a timing task. However, Christina found no significance between his middle level PFB group and his high level PFB group. The present study showed a significant difference between the fast and slow PFB group (equal to Christina's middle and high level PFB), and the fast PFB group and the control group.

This study also contradicted Ellis, Schmidt and Wade, 1968. When using absolute error they found no significance between two groups, one moving a slide with no resistance and the other group moving the slide with an 18.9 kilogram weight. Their movement group, however, was superior to their nonmovement group.

The significant results of the KR factor in this investigation supported the results of K. M. Newell. In his study, KR was withdrawn after either 2, 7, 17, 32, or 52 trials. In each condition other than KRW52, the KR group had a significantly smaller absolute error than the KR withdrawal group.

---


The present research also supported Shultz's results of the main effect of blocks. In both investigations block one significantly differed from the rest of the blocks. Performance in the rest of the blocks demonstrated no significant differences.

Since no other investigation to date has had the subjects return after day one, for the specific purpose of comparing results by days, no comparisons involving this main effect can be provided.

**Summary.** Contrary to many previous investigations in the area of anticipatory timing, this research demonstrated a significant difference in performance of two groups of participants receiving varying levels of PFB. It revealed that performers receiving PFB were more accurate in an anticipatory timing task than those performers who did not receive PFB. The results also indicated that increased levels of PFB increase the accuracy of the performer. This was supported when the group receiving the greater amount of PFB was more accurate than the group receiving a lesser amount of PFB (not statistically significant).

An analysis of the variable error indicated that there was a greater degree of response consistency found within the high feedback group as opposed to the performers receiving a lesser amount of PFB. The results of this study also revealed that the low PFB group differed from the control group in response consistency. This demonstrated that performance was more consistent when the subjects received PFB, and that, as the level of PFB was increased the consistency in response also increased. The present study indicated significant differences between various levels of PFB for response consistency but just failed to show differences for accuracy. Because of the narrow margin by which accuracy
between groups failed, it is possible that a greater number of participants and/or a greater amount of PFB for the fast group may have resulted in significant differences.

It is also quite probable that after a certain amount of trials each group was able to perform as well as the other regardless of the amount of PFB received. The ease of the task involved would make this possible. Once this point was reached by all three groups, they might have depended upon a central representation of the nervous system to sequence their movements rather than PFB. Under these conditions the net results would yield no significant differences between any of the groups.

Another explanation of why the high level PFB group did not differ in accuracy from the low level PFB involves the duration of the effects generated by PFB. The effects of PFB on a task may be short lived. Perhaps overall trials have a tendency to wash out the earlier effects of PFB. This washing out effect combined with the possible switch to central representation of movement control could be responsible for the nonsignificant findings in accuracy between groups one and two.

Regarding consistency of movement, however, all three of the experimental groups significantly differed from each other. This demonstrated that as levels of PFB were increased, movement consistency was increased. These results can be attributed to the extended practice procedure employed by this investigation. This factor allowed for the subjects to more efficiently and effectively use the information acquired through PFB, and to incorporate into their movements those changes of individual abilities other than initially used in the learning of the
The main effect of blocks was significant for both constant error and variable error, and so was the interaction of blocks by groups for constant error. The non-significant results of block by groups for movement consistency can be possibly be explained by the warm-up decrement factor as explained by Schmidt and Nacson, 1971. 85

KR was a significant factor for accuracy, however, although a significant difference existed for KR and NKR, neither one was more accurate. The KR group underestimated by .27 and the NKR overestimated by .28. The KR by groups factor indicated that for greater accuracy PFB should be combined with KR when the two PFB groups were significantly more accurate than the control group with KR but no PFB. The perceptual trace theory86 would seem responsible for the nonsignificant accuracy findings among groups when KR was withdrawn. By the time KR was withdrawn, the task had already been learned and a perceptual trace had been established by all three groups.

Knowledge of results were not a significant factor in performance consistency although the KR group tended to be more consistent (mean .34) than the NKR group (mean .38). Consistency of performance once KR


was withdrawn can again be explained by the perceptual trace theory. Before KR was withdrawn the subject had experienced twenty-four trials. It would seem that this was ample time to form a perceptual trace for a consistent, if not accurate movement, for this rather simple task. The movement consistency experienced after KR withdrawal may also be attributed to the second stage of a two stage theory of motor learning. The motor program theory\textsuperscript{87} states that the second stage of performance no longer depends upon PFB to order movements, but movements are controlled by a central motor program of the central nervous system. Once this stage is reached, performance becomes automatic, and consistency is maintained regardless of the amount of PFB being generated, if any, or the presence of KR.

This research came closer to demonstrating significant differences in accuracy between varying levels of PFB than previous coincident timing studies because of factors incorporated here which were not incorporated in previous studies of the same nature. The most unique aspect of this research involves the day factor. This was the only study involving PFB and a coincident timing skill which had the subjects return for three consecutive days of trials following the first day. This allowed for observation of the performers under extended practice condition, and to compare day by day results of the performers. The day factor supported this researcher's rationale for utilizing extended practice sessions. It was this author's contention that practice had to continue long enough

to allow for the utilization of the skills involved in perceiving and responding to PFB to become an active part of the subject's response. On day one both of the PFB groups were significantly more accurate than the control group, but they did not differ from each other. However, on the second day of practice all the groups differed from each other with the high PFB group being the most accurate.

Over the last two or three days there was little difference evident among any of the groups. This could possibly be due to another type of responding, i.e. motor programming as advocated by Summers (1975)88.

Basically there are three reasons why the results of this research differed from previous research in the same area. Whereas the majority of previous research manipulated PFB levels by varying amplitude of movement, this investigation manipulated PFB via velocity differences. If consistency of input is necessary for PFB to be useful in coincident timing tasks then a constant velocity of the subjects left arm would covary with accuracy of the right hand timing task. This was supported by the results of this research. The groups receiving the higher level of PFB were more accurate and more consistent in their timing performance.

Another aspect unique to this investigation involved the time interval. The subjects were not merely trying to estimate a given time interval, but they were required to learn the interval without prior knowledge as to its duration. This made the subjects rely more

on their timing skills rather than their preconceived conception of a given time period.

Lastly was the concept of extended practice sessions. Previous research on anticipatory timing did not allow the subject an adequate number of trials. This prohibited the subject from fully utilizing the PFB generated from his movement. For the skills which interpret and respond to PFB do not appear until the later stages of practice. In this study each subject was given 200 trials to allow them to utilize their skills in interpreting and responding to PFB.
A. Summary

The purpose of this study was to investigate how the body's internal timing mechanism operates. Specifically, the task was to ascertain if a person's timing accuracy and/or consistency in a coincident timing task was affected by varying levels of PFB. Operating under the confines of the input theory of peripheral timing, a major assumption of this study was that if PFB was a factor affecting timing performance the amount of PFB received had to be consistent from trial to trial. It was also hypothesized that if the amount of PFB was varied the accuracy and/or consistency of the performer would be affected. In order to test these two assumptions PFB was induced to two groups via a left arm movement with a velocity of either 12.33 or 40.00 centimeters per second. The results of these two groups were compared to each other and to a third group which responded without a left arm movement.

The interval to be learned by the subject was 1.5 seconds. It started when the subject initiated his left arm movement. The end of the interval was signalled by a buzzer. A valid supportive test of the input theory would show that the subject's accuracy and/or consistency of response with the right hand would covary with the degree of velocity of the left arm.
Seventy-five right handed male subjects were tested. They were randomly assigned to one of three groups, low PFB, high PFB, or a control group receiving no PFB. Each subject received fifty trials per day for four consecutive days. The trials were divided into blocks of five with a 20 second rest interval between blocks. Trials 1-24 were accompanied by KR. Trials 25-50 were conducted without KR. Each subject wore a blindfold to prevent visual cues.

One of the major results of this study involved the effect of varying levels of PFB on timing accuracy. The results supported the findings of Christina, 1970\textsuperscript{89}, whereby movement groups differed from non-movement groups in the accuracy of an anticipatory timing task. Christina and Schmidt, 1969\textsuperscript{90}, found no significant difference among groups when the PFB level was varied. This investigation indicated that the high PFB group was more accurate than the low PFB group, however, this difference was not statistically significant. A drawback of the Schmidt and Christina study existed in the fact that PFB for the high feedback group was not kept consistent from trial to trial. The work of Ellis, Schmidt and Wade, 1968\textsuperscript{91} was also contradicted by this study. In their study, no differences were found between groups of varying amounts of PFB. The complexity of response and lack of


\textsuperscript{91}M. J. Ellis, R. A. Schmidt and M. G. Wade, "Proprioception Variables as Determinants of Lapsed Time Estimation," \textit{Ergonomics}, 11 (1968), 119-134.
trials may have contributed to the non-significant findings in their investigation.

The results of this research involving blocks of trials by groups indicated that both of the PFB groups were more accurate than the control group. However, contrary to expectation the low PFB group was more accurate than the high PFB group (block one only). The control group was the least accurate of the three groups. These results were due in most part to the underestimation of the time interval by the control group in block one. This supports the results of Quesada and Schmidt, 1970\textsuperscript{92}, but are contrary to the results of Shultz, 1974\textsuperscript{93} when his control group did not differ from any other groups in estimating a time interval. The factor of warm-up decrement may be responsible for this.

The feedback groups in this study exhibited a negative response bias which is directly opposite of the results reported by Quesada and Schmidt, 1970\textsuperscript{94}. Although the KR group in this study differed from the NKR group neither group was more accurate than the other. The KR group underestimated the time interval by approximately the same margin the NKR group overestimated the interval. The test of the simple main effects of knowledge of results by groups indicated that groups receiving both PFB and KR were more accurate in their timing task than the control group.


\textsuperscript{93}Barry Shultz, "The Role of Proprioceptive Feedback in Perceptual Anticipation and Coincident Response Timing," (Ph.D. Dissertation, University of Maryland, 1974.)

\textsuperscript{94}D. C. Quesada and R. A. Schmidt, op. cit., 273-283.
which received KR but no PFB. There were no differences when KR was removed.

The effects of KR withdrawal in this study were the same as the results reported by Ellis et al. 1968. Using the constant error measure there were no significant differences between the KR and the KR withdrawal conditions and the movement and control groups. It has been suggested by Ellis et al. 1968, that withdrawal of KR results in all groups employing a stochastic response strategy. Grose, 1967 offered evidence as to why KR and NKR conditions yielded no significant differences in response consistency. His investigation indicated that subjects can learn to anticipate and time without extrinsic KR. Also supported by this study were the findings of Bilodeau and Bilodeau, 1958, that late in the motor stage of learning, learning can continue without KR.

Christina 1970, Cummings, 1972, and Shultz, 1974 failed to provide evidence that PFB yields more consistent responses. A possible explanation for this is that extended practice sessions are needed for PFB to serve a mediational role in anticipatory timing tasks, and

95M. J. Ellis, R. A. Schmidt, and M. G. Wade, op. cit., 110-134.


97R. W. Christina, op. cit., 125-133.


these studies did not utilize extended practice sessions. Fleishman and Hemple 1954\textsuperscript{101} indicated that various abilities are utilized as practice in a skill continues. It is possible that the skills of anticipatory timing and the effects of PFB in relation to it may not appear until more than the usual number of trials has been attempted. Practice has to continue long enough to allow for the utilization of the skills involved in perceiving and responding to PFB to become an active part of the subject's response. The present study allowed for 200 trials by each subject in an attempt to see when these skills affected the response. The results provided evidence to support the view of extended practice.

On day one of the experiment (after 50 trials, most previous tests used 40 or 50 trials) the two groups receiving PFB were more accurate with their response than was the control group which received no KR. However, the low and high PFB groups did not differ from each other. On day two, and after 50 more trials, all three groups differed from each other with the fast group (high PFB) being the most accurate and the slow group being the least accurate.

As in Ellis' 1969\textsuperscript{102} investigation the high PFB group in this study differed in response consistency from the control group. However, there was no difference in consistency of response between the high feedback group and low feedback group.

Blocks was also a significant factor in response consistency. How-


ever, the difference appears in block one only and can possibly be attributed to the warm-up decrement factor.

Although an analysis of variance did not indicate a significant difference for the KR factor, the groups receiving KR were more accurate than the groups not receiving KR (KR mean 0.034, NKR mean 0.038). Withdrawal of KR did not affect performance consistency and supports Grose's findings (1967) that in a coincident timing task involving receptor anticipation subjects are able to learn to anticipate and time their responses without extrinsic KR. Consistency of response without KR may be attributed to the formation of a perceptual trace during the first 25 trials. In addition, without KR the subjects had no error factor to base movement adjustments on, therefore, few adjustments were made. This resulted in consistent but perhaps inaccurate responses.

In terms of absolute error, the significant differences which occurred between the high level PFB group and the control group in this study supports Christina's results of 1971103. However, where Christina, 1971, and Ellis et al 1968, found no differences among groups with varying PFB levels, this investigation reported a difference between the high and low feedback groups. The low feedback group in the present study did not differ from the control group.

Briefly, performers receiving PFB were more accurate and consistent in their performance than those who did not receive PFB. Results also indicated that accuracy and consistency were increased as the level of PFB increased. The differences among groups were significant for

consistency, but not for accuracy. Consistency was not affected by KR withdrawal, however, KR was a significant factor for accuracy although neither the KR group or NKR group was more accurate than the other. The KR group underestimated the interval by the same margin the NKR group overestimated the interval. Accuracy of the high level PFB group increased significantly over the control group and low PFB group on the second day of trials. Consistency was not affected by the extended practice conditions.

B. Conclusions

Based upon the results of this investigation with regard to the stated problems the following conclusions seem to be in order:

1. High levels of PFB increase the accuracy and consistency of responding to a coincident timing task.

2. Looking across blocks of trials, many of the differences in responding to various levels of PFB were eliminated after trial block one. Since the control group often "caught-up" to the experimental groups this might suggest a role for PFB as a means to combat serious warm-up decrement effects.

3. The absence of a significant difference between groups after day two may involve an alternative response pattern.

C. Recommendations

Following the results and conclusions of this investigation the following recommendations for further research are offered:

1. Further investigation pertaining to levels of PFB and what amounts are necessary to affect performance.
2. Test for retention powers of various groups receiving different levels of PFB on a coincident timing task.
3. Investigate the possibility of an additional stage of responding i.e., motor program.
BIBLIOGRAPHY


