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The effects of force exertion on coincidence-anticipation ability

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THE EFFECTS OF FORCE EXERTION ON COINCIDENCE-ANTICIPATION ABILITY

by

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An Abstract

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ABSTRACT

The study investigated the effects of force, time, and sex on the performance of a coincidence-anticipation task. Two levels of submaximal grip strength, exerted at two intervals prior to the onset of the coincidence-anticipation task, were the variables under investigation. The levels of force exerted at 5 or 15 seconds prior to the coincidence-anticipation task were no-force, 25% of maximum grip strength, and 50% of maximum grip strength. Male and female volunteer subjects were randomly assigned to each of the six experimental and control groups, under the constraint that each group be composed of an equal number of males and females. The major apparatus used in the investigation was the Bassin Anticipation Timer. A runway, consisting of a sequence of light-emitting diodes, approached the subjects from a head-on position. The response apparatus consisted of a telegraph key positioned near the end of the runway. Subjects performed 40 trials per day over a 3-day period. The experimental groups exerted the designated percentage of force, using a hand dynamometer, prior to each timing trial. The timing task required the subject to release a telegraph key at a time coincident with the anticipated arrival of the sequence of lights to a target light. Except for the force-exertion phase, the control groups followed the same procedure as the experimental groups. All subjects received knowledge of results after each trial. Analyses of the data included an examination of the effects of force, time, and sex on constant and variable error measures.

On the average, subjects had a tendency to respond early. The exertion of force at the 50% level significantly affected the accuracy of responses on the coincidence-anticipation task. The consistency of responses was significantly affected by the time interval; subjects in the 5-second treatment groups responded with less variability than the 15-second groups. However, the factor of time interacted with the factor of force. The least variability was exhibited by groups performing 50% of their maximum grip strength at 5 seconds prior to the coincidence-anticipation task. The factor of sex was also dependent upon force in the analysis of consistency in responses. The results supported the hypothesis that proprioceptive feedback, in the form of exerted force, facilitated accuracy in an anticipatory timing task.

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A Thesis Presented to the Faculty
of the School of Health, Physical
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Requirements for the Degree
Master of Science

by
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Ithaca College
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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Thesis of

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submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health, Physical Education, and Recreation at Ithaca College has been approved.

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INTRODUCTION

The successful performance of a complex task requires the organization and execution of coherent movements. Fundamental to successful organization is the ability to select the correct series of movements and to choose the instant to execute initial and subsequent responses (Poulton, 1974; Singer, 1975). An important factor conducive to selecting the optimal point of initiation is a sense of timing. The component of timing, along with the factors of force, direction, and amplitude, is critical to the successful performance of everyday skills (Ellis, 1969; Poulton, 1957). A rather complete example of this timing concept is exemplified in automobile driving, as well as the timing involved in typing or playing the piano.

Sport situations are even more explicit in the demand for proper timing. For example, the initiation of a batter's swing dictates success or failure at the plate. The athlete must determine the rate and direction of the ball, choose the arc of the swing, and then initiate the beginning movement (Rosenbaum, 1975). This complex sequencing is obvious in other sports as well; e.g., tennis, soccer, football, and basketball demand a sense of timing and intercepting ability (Fitts & Posner, 1967). It is evident, therefore, that the development of a sense of timing is an advantage to the child as he or she will be better prepared to deal with judgments of speed and the timing involved in the interception or avoidance of objects (Cratty, 1967; Smith, 1970).

In order for an individual to prepare the correct responses for a variety of situations, it is necessary that he or she anticipate the demands of the task. Thus, the development of the ability of anticipatory timing becomes an even greater asset for successful performance (Poulton, 1952). While some situations demand a response coincident to the arrival of an object or opponent, it is necessary, at other times, to anticipate the avoidance of oncoming objects. This is evident as a measure of safety or to feint the defense. The superior athlete, then, is one who possesses this sophisticated sense of timing. The interception in soccer or football, the timing involved in a quick steal in basketball, and the performance of an effective block in volleyball all require that the athlete be capable of processing spatial and temporal information. The answer of how timing ability develops and the basis of its existence would, therefore, seem to benefit both instructors and students. The search for a basis of timing is critical to all phases of skill development and all levels of performance. "Even the most simple movements involve sequential, coordinated patterns of movement of the various body segments" (Schmidt, 1968, p. 643).

Several persons have dealt with a kinesthetic or a proprioceptive base as a facilitating agent for a sense of timing and control (Ellis, 1969; Goldstone, Boardman & Lhamon, 1958; Paillard, 1960). The explanations are varied; the concept of a proprioceptive basis for timing offers a possible answer to the perplexing questions of skill development. "In the absence of an organ of time, it must be assumed that timing is governed by an undiscovered brain mechanism or is a derived function of one or more of the senses" (Adams, 1977, p. 504). Certain amounts of sensory feedback from proprioceptive cues may provide the information needed to serve as a basis for the facilitation of timing and anticipation ability (Schmidt, 1971). These cues may be generated from joint receptors during movement or from the force required to initiate such movement. The important role of muscular tension in movement was reported in investigations by Sherrington (1906); he presented the fundamental concepts for future study of the influence of proprioception in movement. It is plausible that varying amounts of force can provide basic proprioceptive cues to enhance timing (Bahrick, 1957). This concept of 'muscular attitude' has also been discussed by Gibson (1941) with regard to voluntary reactions. Further research concerning a proprioceptive basis is needed. Perhaps, an investigation of the role of force in conjunction with tasks of anticipation will contribute to a better understanding of timing and motor control.

Scope of Problem

The effects of proprioceptive cues executed prior to an anticipatory timing task were investigated. Two levels of submaximal grip strength, exerted at two intervals prior to the onset of a coincidence-anticipation task, were assigned to groups of subjects that had an equal number of males and females. The effects of these variables were determined by analyzing the constant and variable errors of a series of anticipation trials.

Statement of Problem

The effects of force, time, and sex on the performance of a timing task were investigated with regard to the accuracy and consistency of responses. The effects of three levels of force and two delay intervals (after the force exertion task) on the ability to anticipate the arrival of a stimulus to a designated target were studied.

Null Hypotheses

1. The performance of a force exertion task prior to a timing task will not have an effect on the accuracy of coincidence-anticipation ability.

2. The performance of a force exertion task prior to a timing task will not have an effect on the consistency of coincidence-anticipation ability.

3. The magnitude of force exertion will not have a significant effect on the accuracy of coincidence-anticipation ability.

4. The magnitude of force exertion will not have a significant effect on the consistency of coincidence-anticipation ability.

5. The duration of the interval between the force exertion task and the timing task will not significantly affect the accuracy of coincidence-anticipation ability.

6. The duration of the interval between the force exertion task and the timing task will not significantly affect consistency of coincidence-anticipation ability.

7. Sex will not have a significant effect on the accuracy of coincidence-anticipation ability.

8. Sex will not have a significant effect on the consistency of coincidence-anticipation ability.

Assumptions of Study

1. Subjects adhered to all directions and attended to the task-related signals throughout the three days of testing.

2. Subjects were motivated to perform to the best of their ability on each trial.

3. The subjects belonging to the treatment groups performed the force exertion task in a consistent manner, as instructed in the directions.

4. The muscular contraction involved in the exertion of force is fundamental for the initiation of movement.

5. Subjects were not affected by fatigue during the 20 trials per set.

Definition of Terms

1. Coincidence-anticipation: the combination of information processing and movement execution to predict one's movement in order that it may coincide with the arrival or occurrence of an object or event.

2. Error time: the measure of time, in milliseconds, above or below the perfect anticipation time of zero error.

3. Knowledge of results: information given to the subject after each trial in terms of "early", "late", or "on", in relation

to the exact arrival of the sequence of lights to the target light. (KR)

4. "Early": knowledge of results given to the subject indicating that the subject's response occurred before the arrival of the sequence of lights to the target light; recorded as a negative value.

5. "Late": knowledge of results given to the subject indicating that the subject's response occurred after the arrival of the sequence of lights to the target light; recorded as a positive value.

6. "On": knowledge of results given to the subject indicating that the subject's response occurred within the range of 10 milliseconds, plus or minus, about a perfect response of zero order.

7. Force task: an exerted grip force of 25% or 50% of a subject's maximum, non-dominant hand, grip strength score.

8. Decay interval: the duration of time between the completion of the force task and the onset of the timing task.

9. Constant error: the mean of the algebraic error scores recorded for each trial that describes the overall accuracy of responses.

10. Algebraic error: the signed error score of responses about a 0.00 msec. criterion response.

11. Variable error: the standard deviation of the scores as they vary about the mean, indicating the subject's consistency in responses.

Delimitations

1. Only college-age subjects, enrolled at Ithaca College, were tested.

2. The amount of proprioceptive feedback available to each subject was a function of the resultant feedback of the muscular contraction determined by the exertion of 25% or 50% of the subject's maximum grip strength.

3. The two intervals of time, selected for investigation, were limited to 5 and 15 seconds.

4. The speed of the sequence of lights remained the same for all subjects, on all trials, and for all 3 days of testing.

5. Testing was limited to 3 consecutive days of 40 trials per day.

6. The amount of error time was not reported to any of the subjects during the KR phase of testing.

Limitations

1. Subjects of younger or older age groups could have revealed different results.

2. Exertions of force greater or lesser than the 25% or 50% of maximum grip strength would have provided different amounts of proprioceptive feedback to the subjects.

3. An interval of time greater than 15 seconds or less than 5 seconds may have produced different effects for the factor of time.

4. Different results could have been found with the speed of the sequence of lights at a faster or slower rate.

5. A longer period of testing may have revealed different results.

6. Knowledge of results given in terms of the amount of error time would have provided the subjects with additional information.

Chapter 2

REVIEW OF RELATED LITERATURE

This chapter presents a review of literature in the areas of coincidence-anticipation and the role of proprioception in timing. The first section is an overview of timing which serves as background information for the sections dealing with anticipation and coincidence-anticipation. This is followed by a review of the role of proprioception in timing with an emphasis on trace-decay theory. The final section of this chapter summarizes the relationship of the coincidence-anticipation and proprioception investigations.

Timing Overview

Although timing ability is viewed as a necessary component of skilled movement, few studies had been conducted with an emphasis on an overall timing ability (Schmidt, 1968). Early research within the area of timing was generally concerned with reaction time behavior. Investigations were conducted with regard to the study of speed of response to a presented stimulus. Various reaction time studies (Aiken, 1964; Klemmer, 1956) provided for the manipulation of the certainty of the stimulus occurrence as a function of a subject's speed of response. The reaction time experiments, however, were more concerned with discrete timing ability and failed to report information to explain an overall concept of timing and its relation to complex movement patterns.

It was well established that a sense of timing was an important aspect of skilled movement and was, therefore, included in various definitions and explanations of successful motor performance (Adams, 1961; Dimmond, 1966; Fitts, 1964). A statement by Michon (1967) noted that skilled performance was "the timing between successive elements in a string of actions" (p. 1). It was a general consensus that when time characteristics were more distinguishable subjects were able to improve performance in a variety of tasks. Conrad (1955) reported that accuracy of an individual's approximate responses depended partially on a temporal structure. If subjects were able to adapt to sequenced time limits, then their responses were structured within those time limits and proved to be more accurate. While other factors were important for skilled movement; i.e., direction and force, a sense of timing in conjunction with these factors was shown to yield the best performance (Ellis, Schmidt & Wade, 1968).

The concept of a continuous timing ability was important in the studies concerned with tracking behavior (Adams & Xhignesse, 1960; Noble, Trumbo, Ulrich & Cross, 1966). Several factors under consideration in tracking investigations were display characteristics, task characteristics, and subjects' strategies. The display of a certain task described how the stimulus was presented to the subject. A display was essentially a controlled environment containing the stimuli to which the subject responded. The intensity, rate, and/or motion of a certain stimulus could be manipulated depending upon the design of the experiment and the type of behavior desired. An investigation by Noble and Trumbo (1967) reported that greater "stimulus coherence" (a term to describe consistency in patterning of a stimulus sequency) provided easier task demands in timing behavior. Leonard (1953) found a smoothness in performance when advanced information was available in the display and viewed everyday situations as a display comparable to laboratory settings. When advanced information was available, subjects were allowed to time their responses ahead of the stimulus arrival (Leonard, 1953). Task characteristics of rate and motion of displayed stimuli were investigated by Rosenbaum (1975). The problem of determining rate and motion were viewed as two separate entities: (a) a perception of the rate and the path of an object's motion and (b) the extrapolation of the motion from the display. In a similar investigation of velocity and prediction of motion, Gerhard (1959) had discovered that a common strategy among subjects was a tendency to "get ahead" of the display demands, wait for the stimulus to arrive, and then to make a last minute adjustment in the required response. The task involved the interception of two lights.

The timing of responses ahead of the arrival of the stimulus was a major reason for the interest in anticipatory behavior. In an investigation as early as 1948, Craik had noted the emphasis on anticipatory behavior in subjects' strategies. A report by Helson (1949) reinforced the literature on behalf of anticipation as an asset in motor performance. Similarly, Bartlett and Bartlett (1959), in a comment on reaction time studies, reported that most subjects appeared to adapt a type of anticipatory strategy in their responses as they became more experienced. Thus, the ability to predict the occurrence of a stimuli, as well as the critical characteristics of the task, became a primary concern of investigators involved in the area of timing (Poulton, 1957).

In summary, research in the area of reaction time provided the foremost view of timing behavior. Reaction time studies generally controlled for the ability to anticipate by randomization of fore-periods, or uncertainty in the occurrence of stimuli (Schmidt, 1968). Eventually, the importance of anticipatory behavior was recognized by several investigators (Craik, 1948; Helson, 1949; Leonard, 1953). The heightened interest in a "jump the gun" type timing ability brought attention to anticipation as a critical component of successful performance (Fitts, 1964). The predictive ability of the subject was a growing concern among those investigators involved in the study of timing behavior (Poulton, 1957).

Anticipation

The growth of interest in predictive and anticipatory behavior brought with it new terms and concepts. Investigators searched for definitions which would adequately describe the timing ability involved in anticipation, as well as the critical factors that influenced anticipatory timing behavior. Adams and Xhignesse (1960) emphasized the role of task coherency for anticipatory behavior in a two-dimensional tracking task. Their results indicated that a predictive type ability allowed the subject to respond to more than one task if the two tasks were of "high coherency". Task coherency was determined by similar spatial or temporal characteristics. If only one source was predictable, the subjects still maintained an advantage because they needed to orient only to the uncertain event. The terms of "beneficial" and "ideal" anticipation, developed by Adams and Xhignesse (1960), were used to explain two types of predictive behavior: beneficial anticipation described the ability to perform tasks at a much faster time than the expected reaction time interval, and ideal anticipation was the ability to respond coincident to the stimulus.

An in depth report by Poulton (1957) provided information concerning three types of anticipation. "Effector anticipation", the most elementary form of prediction, was described as the ability to predict the nature and size of muscular contractions required in a task. The concept of "receptor anticipation" explained a prediction involving accurate judgments about the environment and the ability to match one's response with the position or speed of the stimulus. It described a type of duration of response characteristic. The most complex form of prediction was termed "perceptual anticipation". This concept encompassed both effector and receptor abilities; it described the ability to predict future positions of target or movement time. Leonard (1953) had combined the concept of receptor and effector abilities in the context of information processing. "Receptor-effector anticipation depends on the presence of a signal that can be observed and acted upon ahead of the action point" (Leonard, 1953, p. 147).

In a review of timing and anticipation, Schmidt (1968) divided the "perceptual anticipation" class into two areas: spatial and temporal. Spatial anticipation referred to the prediction of where a stimulus will occur, and temporal anticipation involved the ability to predict the time of arrival of the stimulus. Both types of information gave the subjects important tools for improvement and success in tasks of tracking behavior. This type of advanced information was described as an aspect of preview by Poulton (1964), who developed the terms of "speed anticipation" (temporal) and "course anticipation" (spatial). Poulton attributed the decrease of error rate in tracking tasks to the amount of preview available.

The general conclusions of the aforementioned investigations presented an underlying theme in favor of anticipatory timing as a necessary component for success in skills. Whether the tasks were continuous or discrete in nature, results supported anticipation as a critical strategy in performance (Adams & Creamer, 1962a). A summary of the concepts involved in anticipation was stated by Christina (1976): "Anticipatory timing involves the initiation of an accurate movement response before the actual occurrence of the environmental stimulus event" (p. 188).

Coincidence-Anticipation

The acceptance and discussion of anticipatory timing as a testable concept led to experimentation with tasks designed specifically to test anticipation ability. Slater-Hammel (1960) initiated this trend, and was foremost in the investigation of coincidence-anticipation. In contrast to reaction time studies, investigators encouraged the use of anticipatory timing in order to meet the demands of the task.

Belisle (1963) first brought emphasis to the term "coincidence-anticipation" in a replication of a study by Slater-Hammel (1960). Although Slater-Hammel had made several references to the term throughout his investigation, he preferred to describe the timing tasks as being "transit reactions". A variety of definitive terms were used: Poulton (1952) viewed the tendency to anticipate as a concept of "prediction", while Gottsdanker and Edwards (1957) chose to view the behavior as a "prediction of collision". In a broader sense, Whiting (1968) noted that coincidence-anticipation was the underlying basis of "ball skill". Primarily though, the work of Slater-Hammel (1960) was the first study that actually investigated the characteristics and nature of coincidence-anticipation. The major purposes of the study were to examine the accuracy and reliability of transit reactions, to obtain estimates of the duration of refractoriness, and to compare refractoriness results with measures of reaction time.

The design and method of the study by Slater-Hammel (1960) served as a model for Belisle (1963). The apparatus used was a clock-like display; the face of the clock had a white background upon which a black sweep-hand revolved. A fixed marker was located at a position 800 msec. from the start of the sweep-hand. The subject's task was to release a signal key as the moving pointer passed over the fixed marker. A reliability coefficient of .95 over two test days indicated that error measures in transit reactions were consistent; the two days of testing were conducted without KR. A second experiment introduced knowledge of results and catch trials. The results revealed a significantly smaller error rate when KR was provided; a reliability coefficient of .84 was deemed adequate. Introduction of the catch trials resulted in the subjects delaying the initiation of their responses. A refractory period of 140 msec. was reported. The study by Belisle (1963) revealed results similar to Slater-Hammel (1960). Knowledge of results led to more accurate responses, reliability was lower when KR was introduced, and catch trials adversely affected accurate responding. A later investigation by Haywood (1975) failed to find differences among groups performing under three KR conditions: no KR, qualitative KR, or quantitative KR. She attributed the results to the possibility that adequate KR was inherent in the task.

Few studies were conducted following the initial investigations of Slater-Hammel (1960) and Belisle (1963). A renewed interest developed in coincidence-anticipation with the advent of increasing investigation into the preceptual-motor ability of children. It was generally agreed that adults were exposed to many coincidence-anticipation situations in their everyday activities (Schmidt, 1968). This experience of most adults reduced the naievete as subjects, and led to relatively accurate behavior in early trials.

Thus, developmental research with children allowed new factors to be introduced with hopes of discovering the essential components of coincident-timing. A study by Stadulis (1971) involved a task whereby the subjects (7, 9, & 11 year olds) were required to release a telegraph key at the same time that a ball-bearing was propelled down a chute at four different speeds. There were significant results with regard to the factor of age. The older subjects were more accurate at the two slower rates of the object projection than were the younger subjects. There was also a tendency to respond before the time of intercept. Similar age effects were found by Dorfman (1977) in a study that required subjects to anticipate the interception of two dots on a cathode-ray oscilloscope. Older groups performed with lower absolute error than the younger groups, but the age groups of 14-15 year olds and 18-19 year olds did not significantly differ from each other. Dorfman attributed this improvement over age to the developmental process. Williams (1968) failed to find a significant age effect upon the judgment of moving objects, whereas Stadulis (1971) and Dunham (1977) were in agreement with increased accuracy with increased age.

Although an increase in accuracy appeared in older subjects, a reverse effect was found for females in a recent investigation by Stadulis and Rydzell (1978). The groups of 7, 9, and 11 year old females decreased in accuracy over age. Support for this effect of sex was also reported by Dorfman (1977) and Dunham (1977). Males were found to be significantly more accurate in performance as measured by constant error. A study by Ridenour (1974), which involved a paddle-ball type contact to be made with a moving object, also revealed superior performance by males. Ridenour made note that hesitation in initiating contact (reflective behavior) may be more typical for girls than for boys. A similar note was suggested by Dunham (1977); he viewed the boys as being more interested and attentive to the task, and thus they were presumed to be more motivated to perform more accurately. In contrast, Stadulis (1971) and Williams (1968) failed to find significantly superior performance in male subjects.

As previously mentioned, subject characteristics of age and sex were investigated by those people involved with the perceptual motor development of children. Another aspect of development is the actual movement characteristics of the subject. The length of time encompassing the decision to initiate movement plus the actual movement was of importance in an investigation by Schmidt (1967). The results of the investigation by Schmidt (1967) revealed a tendency to establish a relatively constant movement and then to readjust a starting time in the event of errors in responding. Further support for these results were reported in a follow-up study (Schmidt, 1969).

Many of the concepts of coincidence-anticipation were of primary importance in ball skill investigations conducted by Whiting (1968) and Nessler (1973). The major concern of the ball skill investigations involved the length of viewing time necessary to catch or make a response to the oncoming ball. Conflicting evidence resulted in questioning the different perceptual styles of subjects. Picado (1977) continued this line of investigation in a study designed to test the difference of perceptual styles in a coincidence-anticipation task, but no significant differences were found between augmenters and reducers (styles of perceiving information from the environment).

In summary, several discrepancies regarding the factors of age, sex, perceptual style, and knowledge of results made it difficult to generalize across all studies in the search for a concise definition of the critical elements of coincidence-anticipation. Through the work of Slater-Hammel (1960), and the later investigations dealing with developmental factors (Dorfman, 1977; Dunham, 1977; Ridenour, 1974; Williams, 1968), Stadulis (1972) was able to conclude that coincidence-anticipation ability involved three distinct events. Stadulis (1972) viewed the events as: (a) a pre-release phase (attention to the source of a moving object), (b) the object flight phase, and (c) the response phase (the attempt to intercept). This breakdown into three phases provided a complete analysis of coincidence-anticipation type skills.

Proprioceptive Factors

The search for an underlying mechanism on which to base a sense of timing was approached from two different areas of research: (a) investigators dealing with external events as an explanation, and (b) investigators dealing with internal events (Michon, 1967). The studies concerned with the cue theories of internal events provided the main thrust of the research on the role of proprioception in anticipatory timing ability.

Activation and Arousal

Proprioception had been used to describe a variety of processes or receptors that receive information, in some manner, and provide feedback for normal functioning. Dickinson (1976) noted that the many definitions and uses of the terms proprioception and kinesthesis made it difficult to arrive at a suitable concept for all feedback activity in an overall awareness of the proprioceptive system.

An early area of study dealt with the concept of activation and arousal. It was hypothesized that heightened awareness would enhance performance. The source of activation was viewed as increased muscular contraction, thereby producing a degree of readiness or "set". Duffy (1932), foremost in the area of arousal, examined muscular tension and its effect on the quality of performance. The investigation involved an exertion of pressure upon hand-held dynamographs and the performance of a variety of tasks. The results were in support of certain degrees of tension as a facilitating agent in performance of the tasks. "It appears probable that a moderate degree of tension offers the greatest advantage since very high tension probably tends to be disruptive and very low tension probably involves lack of alertness or effort" (p. 546). A study by Freeman (1938) reinforced the idea of increased tension yielding better performance. He found that the number of possible finger oscillations increased when tension load increased. Although there were a number of reports concerning the advantage of muscular tension (Clarke, 1968; Gibson, 1941), some investigators expressed concern about the inhibitory effects (Courts, 1942; Parker, 1973).

Further investigation by Duffy (1957) revealed an emphasis on subject individuality. She suggested that high degrees of activation may provide increased sensitivity, alertness, and coordinated responses to the environment. However, "the tendency to be frequently and intensely aroused leads no doubt to fatigue and to a consequent reduction in vitality" (p. 266). This reduction in vitality occurred in a study by Parker (1973). The investigation examined the effects of varying degrees of grip strength on a time estimation task. The results revealed most accurate performance by the groups who performed a force equal to 50% of their maximum grip strength; whereas, a decrease in performance was evidenced in the non-force group and the group performing 75% of their maximum grip strength. The effects revealed a trend towards an inverted U theory.

Although the research in the area of activation and arousal provided some insight into the role of proprioception and control of movement, it neglected to develop the "how" of its facilitating properties. This provoked further research into proprioception and the control of movement (Ellis, 1969). While a number of investigations reported support for the importance of proprioceptive feedback (PFB) for motor control (Bahrick, Fitts & Schneider, 1955; Fleishman & Rich, 1963), some investigations offered conflicting evidence, and investigators questioned the facilitating effect of PFB (Jones, 1973, 1974; Price, 1974).

Trace Decay Theory

After much investigation into verbal literature and memory systems, Adams (1971) proposed a closed-loop theory of motor learning. The theory was described as a two-state concept based on the existence of a perceptual trace and a memory trace. "It is a complex distribution of traces in a learning situation that has a series of trials" (Adams, 1971, p. 125). The trace decay theory would serve as a basis for the experimental designs of later investigations, and was important in the development of a proprioceptive trace hypothesis.

The relationship between the memory and perceptual trace summarized the primary concept of the theory. The perceptual trace requires feedback after the response begins; whereas, the memory trace selects the response and initiates movement. The feedback available for the development of a perceptual trace was found in proprioceptive stimuli. This source of feedback was viewed as movement, pressure, or tactile stimuli. While others had maintained that muscles provided the necessary feedback for movement (Sherrington, 1906), Adams (1977) emphasized the joint receptors as the primary source of feedback.

The feedback required to strengthen the perceptual trace was subject to forgetting as Adams (1971) had indicated. Thus the theory became a popular test for short-term memory investigations and provided fundamental concepts in the area of learning of motor tasks. "The movement on each trial lays down a trace, and this trace weakens as forgetting processes operate. The composite of old and new traces is the distribution. On any particular trial the response is to a dominant mode of the distribution" (Adams, 1971, p. 125). These concepts proved to be important to the motor memory investigations and provided the framework for the investigations by Adams and Creamer (1962b) dealing with time-varying proprioceptive trace theory.

The area of motor short-term memory was fundamental in the development of the investigations dealing with the factor of time as the determinant of forgetting. Therefore, the trace-decay theorists had held to the general hypothesis that forgetting was a direct function of the time interval between performance of a task and its recall. Melton (1963) proposed three theoretically separable events that influenced performance:

> (1) the events on trial $\underline{n}$ that result in something stored for use in trial $\underline{n}$ + 1, (2) the storage of the product of trial $\underline{n}$ during the interval between $\underline{n}$ and $\underline{n}$ + 1, and (3) the events on trial $\underline{n}$ + 1 that result in retrieval and/or utilization of the stored trace of the events on trial $\underline{n}$. (p. 2)

Adams and Dijkstra (1966) initiated investigations in the motor learning area of short-term memory. A lever positioning skill served as the recall task. Retention intervals of 5, 10, 15, 20, 50, 80, and 120 seconds were tested for the effect of varying time intervals on recall. The interpretation of results indicated support for the hypothesis of a rapidly decaying memory trace over increased time intervals. An investigation by Norrie (1968) tested the effect of varying rest intervals of 30 seconds, 90 seconds, and 4 minutes on the ability to reproduce a force value. The rest interval represented the decay interval. Results suggested a kinesthetic after-effect that decayed after the 30-second rest period. Subjects exerted more than the criterion force when attempting to reproduce immediately after the test force.

Some investigators showed concern for proprioceptive cues derived from counting or tapping during the so-called "rest interval", thereby creating an interference effect (Boswell & Bilodeau, 1964; Postman, 1964). The inconsistency of results led to a major investigation by Pepper and Herman (1970). The subjects' task involved the application of a given magnitude of force in a given direction by pushing or pulling a control knob. Variables tested were the length of the retention interval, rehearsal opportunities during the retention interval, the application of various magnitudes of interpolated forces, and the number of repetitions of the force response. The results of the study were interpreted as a support for a combination of a response set concept and the trace decay hypothesis. Greater errors were reported for the groups performing an interpolated activity than for the groups who merely rested during the interval. The length of the retention interval, as it increased from 12 to 30 seconds, affected the subjects by an improvement in recall. The subjects' tendency to overshoot the recall force was considered a response set, and the increase in the time interval allowed for the decay of the trace. Therefore, subjects became more accurate as the length of the interval increased. An investigation by Laabs (1973) led to the proposal of a kinesthetic memory code and support of the decay hypothesis. "When S has to reproduce movements based on weak memory traces, his reproductions will be more variable than if the memory traces were strong" (p. 177).

Proprioceptive Feedback/Anticipatory Timing

The time-varying features of the trace decay and the manipulation of the rest interval in many short-term memory studies proved to be an important basis for the study of proprioceptive traces and their role as cues for a future response. Adams and Creamer (1962b) had discussed the possibility of time-varying proprioceptive traces as the stimuli needed to provide cues at time t which would allow anticipation of the correct response at $t + \Delta t$. An investigation by Bahrick et al. (1955) and Ellis et al. (1968) reviewed problems of methodology and equipment design in reference to proprioceptive-type studies. Speculation and questions surrounding the concept of timing as a function of proprioceptive cues continued to increase. Although Adams and Creamer (1962b) had revealed evidence for proprioception as a cueing mechanism for responses, few investigations had been conducted in the area.

A study by Schmidt and Christina (1969) attempted to eliminate past problems of mechanical effects that had confounded the proprioceptive effects. Their task involved the manipulation of proprioceptive feedback in a different limb than the responding limb. The feedback consisted of minimal, moderate, or large size rotary movements of the left arm, while the subject executed a timing response with the right hand. Schmidt and Christina hypothesized that greater left arm activity, during the interval to be timed, would result in increased timing accuracy. The timing task required the anticipation of the coincidence of two pointers, one stationary and one moving. Results indicated that the proprioceptive feedback groups performed with greater anticipation than the minimal feedback groups. Although the general hypothesis was supported, it was noted that the feedback needed to be consistent from trial to trial in order to provide a basis for anticipation and timing. Christina (1971) also conducted a study involving three levels of proprioceptive cues. The left arm movement consisted of pushing a slide control with and without a 3.4 lb. load attached. Subjects were required to perform the task prior to a 2-second interval. The subjects anticipated the end of the time interval and released a response key with the right hand. Another facet of the experiment examined the effects of left arm movement performed during the timing task. Results failed to reach significance among groups, but within subjects consistency increased for the moderate and maximum feedback groups. In a similar investigation, passive left arm movement was performed prior to a right hand response to a 2-second interval (Quesada & Schmidt, 1970). The problems involved with the consistency of movement led Quesada and Schmidt to control the left arm proprioception source. The subjects' task involved the release of a response key coincident with the end of a two-second interval. Greater accuracy was found for the PFB group as measured by algebraic error, as well as increased consistency. The results supported the decay hypothesis as proposed by Adams and Creamer (1962a). Schmidt (1971) summarized the aspects of the decay hypothesis by addressing three major considerations; (a) short-term memory restrictions, (b) length of decay interval, and (c) consistency of preliminary movement (proprioceptive feedback source). An increase in the amount of proprioceptive feedback activity (in short-term memory) generated at time "t" is hypothetically advantageous at time t + Δt. In other words, cues available at an initial response (time "t") will provide useful information for the next response at some future time (Δt).

> This leads to the prediction that if preliminary movement at time "t" has large force or amplitude requirements so that it generates considerable proprioceptive feedback, then there should be greater proprioceptive feedback in short-term memory, a greater rate of decay in the next few seconds, and less lag in the mechanism for triggering the subsequent response, with the result that the timing of the response at time "t + Δt" will be more accurate. (Schmidt, 1971, p. 389)

Schmidt (1971) continued to emphasize the need for future research into proprioception as a basis for anticipatory timing especially with regard to different display and task requirements in order that an appropriate explanation be available for timing in motor skill acquisition.

The proposal by Sherrington (1906) concerning the important role of muscular tension in movement served as the fundamental concept for further investigations into the role of proprioception in timing and movement control. Early studies in the area of activation and arousal provided evidence for the possibility that muscular contraction was related to accurate performance (Courts, 1942; Duffy, 1932). A testable "closed-loop" theory developed by Adams (1971) brought attention to the short-term memory characteristics of proprioceptive traces and an emphasis on the time-varying properties of proprioceptive feedback (Adams & Creamer, 1962a). The hypothesis of proprioception as a determinant of timing ability was further investigated by examining feedback from one task as an aid in some future task. The variety of investigations, and the somewhat conflicting results, emphasized the need for continued research in the search for an adequate explanation of proprioception as a basis for anticipatory timing.

Summary

Early investigations dealing with timing ability were primarily concerned with reaction time behavior. The possibility of anticipation in reaction time studies was prevented through experimental control of the certainty of the stimulus occurrence. However, anticipatory behavior became evident in a number of studies and was included as an important component in the description of skilled performance.

The concept of coincidence-anticipation was first mentioned by Belisle (1963). Tasks were designed specifically to test anticipatory timing ability. Although few studies had been conducted in the area of coincidence-anticipation, there was support evidenced in the earlier timing studies. The emphasis on anticipation as an asset in various timing tasks led to research in the area of perceptual-motor development.

Investigations of motor skills in children were reviewed in reference to the renewed interest in coincidence-anticipation ability. Factors receiving much attention were task characteristics (speed and/or motion) and subjects' characteristics (age or sex). The variety of results in developmental research provoked intensive investigations into the search for a basis of timing ability.

An overview of a proprioceptive trace-decay theory was reviewed as a fundamental hypothesis in the examination of motor skill acquisition. A number of the motor short-term memory investigations were conducted under the assumption that a time-varying proprioceptive base was involved in the learning or memory of certain movements or exertion of force. It was also hypothesized that feedback of a proprioceptive nature should aid in the timing required for future responses. This concept was summarized by the investigations of Adams and Creamer (1962b). The hypothesis stated that proprioceptive feedback from time "t" could be used to facilitate responding at time "$t + \Delta t$".

A number of studies found support for the decay hypothesis whereby feedback was generated from movement. The variety of experimental designs, however, made it difficult to arrive at conclusive evidence for the type of proprioception involved in anticipatory timing. Investigations allowing proprioceptive feedback prior to and during a timing task also evidenced confounding results. The major conclusions, though, of the reviewed studies, favored the relationship of timing and proprioception. An important note of all research emphasized the need for more investigation into the proprioceptive characteristics involved in anticipatory timing ability.

Chapter 3

METHODS AND PROCEDURES

The purpose of this chapter is to present the methods and procedures that were used in the gathering and analyses of data. The following areas were described: description of subjects, testing equipment, method of data collection, scoring of data, and treatment of data.

Description and Selection of Subjects

The subjects were 48 volunteer male and female undergraduate and graduate students enrolled at Ithaca College during the spring semester of 1978. Subjects ranged in age between 19 and 30, with a mean of 21.2 years. There were eight subjects randomly assigned to each of the six experimental and control groups under the constraint that each group was composed of an equal number of males and females. The majority of the subjects (89.6%) were right hand dominant, while the remaining 10.4% were left hand dominant.

Testing Equipment

The major apparatus used was the Bassin Anticipation Timer, designed by Dr. Stanley Bassin as a test of one aspect of visual acuity. The display was comprised of two connected runways (76.2 cm x 8.89 cm x 6.98 cm) consisting of 36 light-emitting diodes L.E.D. lamps) located 4.44 cm apart. The sequency of L.E.D. lamps started at a yellow warning light 183 cm. away from the response key and terminated at the end of the runway 35.5 cm from the response key. The response key was located on a table 30 cm from the proximal edge of the runway apparatus. The warning light represented the time between the onset of the yellow lamp and the initiation of the sequence of lights, and was illuminated prior to each sequence. This time period could be varied between 0.5 and 3 seconds in increments of 0.5 seconds. A digital clock recorded the error time in milliseconds ranging from 0.001 to 9.999 seconds. The speed of the light sequence could be regulated at speeds ranging form one to 500 miles per hour. The control unit for the regulation of speed, the warning period selection, and the digital clock display is shown in Figure 1. The results of a pilot study, conducted in the Psychomotor Lab at Ithaca College in February 1978, indicated that a speed of 10 mph. was appropriate for the present investigation (see Appendix A).

A telegraph key, mounted on the table in front of the subject and centrally located as to allow the subject's forearms to rest comfortably on the table, served as the response apparatus. A Stoelting hand dynamometer, calibrated in kilogram units was used for the force exertion task. This apparatus was positioned to the side of the non-dominant hand of the subject and away from the telegraph key so as not to interfere with the response phase of the testing; it is shown in Figure 2. Two Hunter decade interval timers were used to regulate the decay interval period, and the inter-trial interval. A low-intensity light illuminated the response area. This allowed the subjects to view the hand dynamometer and the target light-area of the runway.

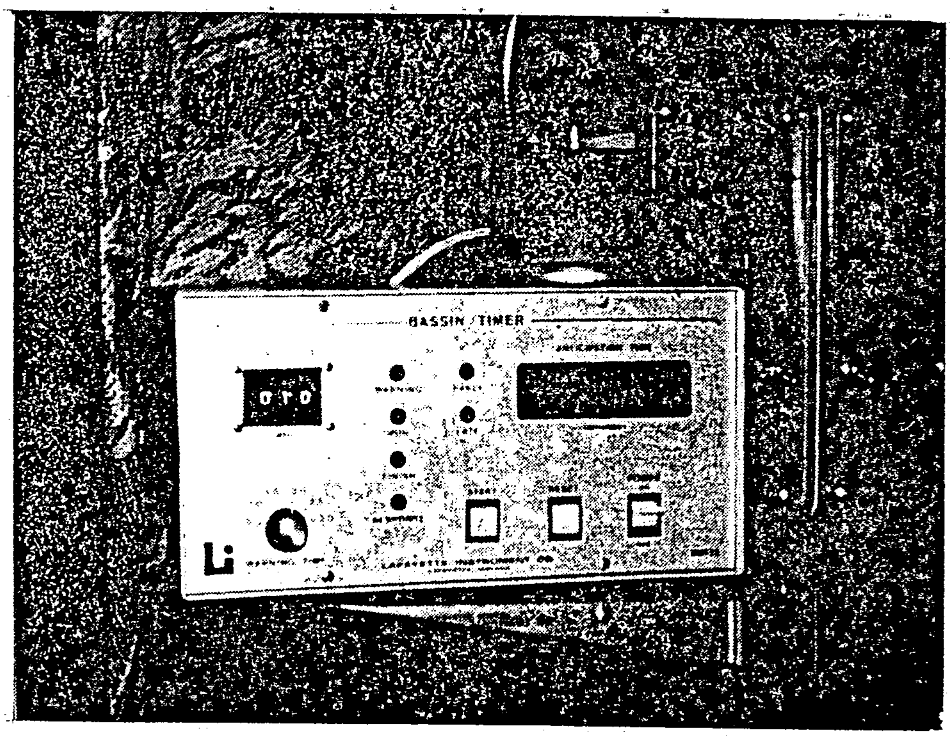

Figure 1

Control Unit of Bassin Timer Apparatus

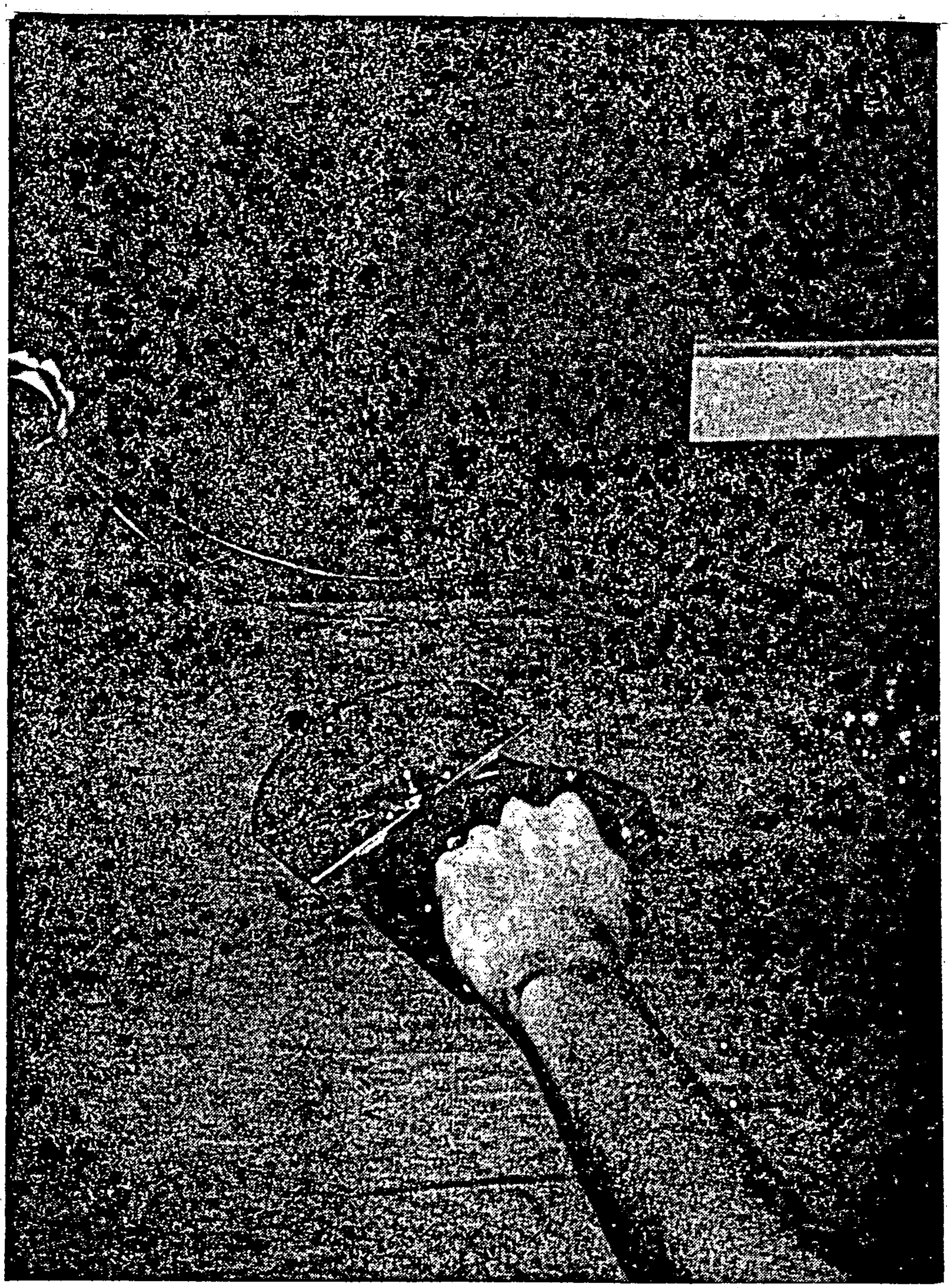

Figure 2

Relationship of Dynamometer and Telegraph Key Apparatus

Method of Data Collection

Testing was administered over a three-day period. After entering the lab, the subjects were instructed to select a number, thereby randomly assigning themselves to one of the six experimental and control groups. A total of eight subjects, four males and four females, comprised each group. An informed consent form, which described the demands of the experiment, was then presented to all subjects (see Appendix B).

The randomized group assignment had determined the percentage of maximum grip strength, no-force, 25%, or 50%, and the time interval for each subject. A five or 15-second delay from the force exertion task to the onset of the signal lamp described the two time intervals. All groups were defined by a level of force paired with a time interval, i.e., NF/5 sec., NF/15 sec., 25%/5 sec., 25%/15 sec., 50%/5 sec., and 50%/15 sec.

Subjects in the experimental groups were given two grip strength trials to determine their maximum grip strength. The mean of the two trials was recorded on the data sheet along with the respective percentage of the maximum grip score and the assigned time delay. The percentage value of the grip score was marked on the dynamometer to serve as a reference point for the force exertion task.

All of the subjects were then positioned in front of the apparatus so that the lights on the runway approached them in a head-on fashion. The subjects were instructed to rest their forearms on the table in front of them as illustrated in Figure 3. Pre-recorded

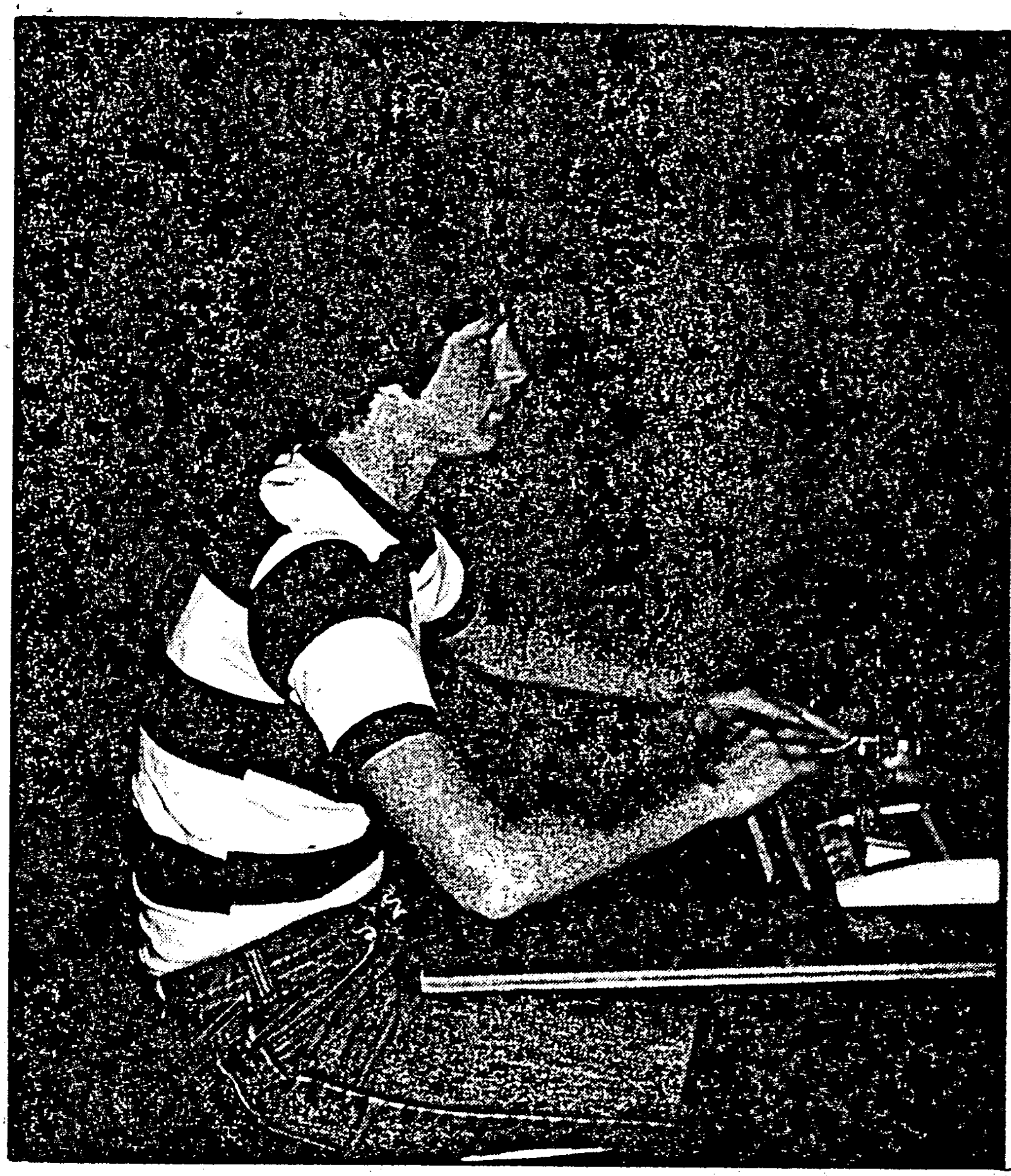

Figure 3

Subject in "Ready" Position to Perform Timing Task instructions were then presented to the subjects (see Appendix C). Any questions concerning the procedures were answered at this time. An abbreviated form of these instructions were read to the subjects at the beginning of each testing session.

The treatment groups exerted 50% or 25% of their maximum grip strength prior to the timing task. Control groups were instructed to rest their non-dominant forearm in a comfortable position on the table during this phase.

Each trial was then administered according to the following procedure:

(a) The experimenter initiated the force-phase of each trial by prompting the subject with a verbal signal of "grip" for the experimental groups, and "ready" for the control groups.

(b) Commands of "exert" and "release" followed the initial prompt to the experimental groups to insure consistency in the "facilitating" force task.

(c) The experimenter then initiated an interval timer to measure the respective delay intervals.

(d) At the conclusion of the time interval, the random foreperiod began (signal light illuminated), and the sequence of lights followed. The end of this phase coincided with the start of the timing task trial.

The subjects performed the coincidence-anticipation (timing) task with their dominant hand (writing). The index and second finger of the dominant hand were placed on the telegraph key in a down position at the start of each timing trial. The subjects' task was to respond at a time coincident with the anticipated arrival of the sequence of lights to the target lamp by releasing their fingers from the telegraph key.

After the response, the experimenter recorded the subject's error time in milliseconds, and then gave the subjects knowledge of results in terms of "early", "late", or "on". A response made prior to the arrival of the sequence of lights to the target light was designated as "early". A response made after the arrival of the sequence of lights to the target light was determined to be "late". Error times of plus or minus 0.010 seconds were regarded as "on target" responses. The KR was given to the subject approximately five seconds into the 15-second inter-trial interval. The subjects completed 40 trials per day by the aforementioned procedures, with a 1-minute rest between Trial 20 and Trial 21.

Scoring of Data

Error time was recorded in milliseconds and defined as the time prior to or following a perfect anticipation (0.000 seconds). The early responses were assigned a negative value, while the late responses were recorded as positive. The mean algebraic error (constant error) was computed for each subject. The variable error, the measure of response consistency, was the standard deviation of the error scores about the constant error.

Treatment of Data

An intraclass correlation technique determined the reliability of the trial scores across all subjects. A 2 x 3 factorial arrangement of treatments was the design used in this study. Two analyses of variance were used to determine if there were significant differences among treatment combinations, as measured by constant and variable error scores.

Summary

The methods and procedures of this investigation were described under the following areas: description of subjects and testing equipment, data collection, scoring of data, and treatment of data. The subjects were 48 volunteer male and female students enrolled at Ithaca College during the spring semester of 1978. There were eight subjects (four males and four females) randomly assigned to each of the six experimental and control groups.

The major apparatus used was the Bassin Timer. A sequence of 36 light-emitting diodes comprised the display. The subject responded to the illumination of the target light by coinciding the release of a telegraph key with the arrival of the sequence of lights to the target light. A Stoelting hand dynamometer, calibrated in kilogram units, was used for the force-exertion task.

All subjects performed 40 trials for each of the three days of testing. The experimental groups exerted 25% or 50% of their maximum grip strength prior to the timing trials. An interval of 5 or 15 seconds separated the end of the force task and the onset of the timing task. All groups performed the coincidence-anticipation task with their non-dominant hand (writing hand). Knowledge of results were then given to each subject in terms of "early", "late", or "on", indicating the relationship of the subject's responses to the actual arrival of the light sequence to the target light. Error time was recorded in milliseconds. The early responses were assigned a negative value, while the late responses were recorded as positive. The mean of the algebraic scores was computed and labeled constant error. The standard deviation of the error scores about the constant error measure was termed variable error. An analysis of variance examined the effects of the factors of force, time, and sex on constant error and variable error measures.

Chapter 4

ANALYSIS OF DATA

This chapter presents a summary of the analyses of data. The major analyses are presented in the following order: analysis of trials for reliability, analysis of constant error scores, analysis of variable error scores, and a summary of the analyses.

Reliability

The first analysis examined the reliability of raw scores for all subjects, and was determined by an intraclass correlation technique. The reliability coefficient is representative of the between-subjects variance minus the error variance, divided by the between-subjects variance. Table 1 presents the between-subjects variance, the error variance, and the reliability of the raw scores for trials 1 through 40 for each subject on the third day of testing. A reliability coefficient of .85 was determined.

Analysis of Constant Error Scores

The algebraic error score indicated the amount of error time on each trial. Early responses, those occurring before a perfect response of 0.00 msec., were recorded as a negative score; late responses were recorded as a positive value. The mean of the algebraic scores was computed and labeled constant error (CE). The constant error revealed the accuracy of each subject. The mean constant error scores for each group are presented in Table 2. The CE scores ranged from 1.35 msec. for females in the 50%/15 sec.

Table 1

Between-Subjects Variance, Error Variance,

and an Intraclass Estimate of Reliability

Between-Subjects Variance	Error Variance	*R*
12311.588	1789.942	.854

Table 2

Mean Constant Error Scores in Milliseconds

across Factors of Force, Time, and Sex

	Levels of Force	Interval Duration	Male	Female	M for Treatment Condition
		5 sec.	-11.756	-18.826	
	NF				-12.805
		15 sec.	-12.935	-7.705	
M for Males and Females across Time			-1.345	-13.265	
		5 sec.	-28.216	-3.859	
	25%				-16.401
		15 sec.	-19.418	-14.109	
M for Males and Females across Time			-23.817	-8.984	
		5 sec.	-11.331	-12.693	
	50%				-2.111
		15 sec.	14.224	1.353	
M for Males and Females across Time			1.446	-5.669	
		5 sec.	-17.101	-11.793	-14.447
		15 sec.	-6.042	-6.820	-6.431
M Males			-11.572		
M Females				-9.306	
Grand Mean					-10.439

group to -28.21 msec. for male subjects in the 25%/5 sec. group. The grand mean for all males was -11.57 msec., while females averaged -9.30 msec. All groups were early in their anticipation scores except for the males who performed the 50% maximum force exertion prior to the timing task. The female subjects in the 50%/ 5 sec. group also exhibited a late response tendency, but the overall group mean for females at the 50% maximum force level was -5.66 msec. The most accurate group, revealed by the smallest CE score, was the 50% maximum force group as indicated by a CE value of -2.11 msec.

An analysis of variance determined the effects of the factors of force, time, and sex on the CE scores. A summary of the results is shown in Table 3. With 2 and 36 degrees of freedom, an F ratio of 3.32 was needed for significance at the .05 level of confidence. The main effect of force revealed an F ratio of 3.35 and was, therefore, significant at the .05 level of confidence. Consequently, the null hypothesis of the effects of varying magnitudes of force on the accuracy of responses was rejected. The interactions of force by time, force by sex, and force by time by sex failed to reach significance.

An F ratio of 4.17 was needed for significance at the .05 level of confidence with 1 and 36 degrees of freedom. The main effects of time and sex variables on CE scores revealed F ratios of 2.92 and 0.23, respectively, and, therefore, were not significant. Similarly, the interaction of time by sex failed to reach

Table 3

Summary of ANOVA across Factors of

Force, Time, and Sex

	Sum of Squares	Degrees of Freedom	Mean Squares	*F*
Force	1767.925	2	883.962	3.35*
Time	771.650	1	771.050	2.92
Sex	61.589	1	61.589	.23
Force x Time	898.492	2	449.246	1.70
Force x Sex	1024.418	2	512.209	1.94
Time x Sex	111.105	1	111.105	.42
Force x Time x Sex	535.410	2	267.705	1.01
Subjects within Groups	9482.570	36	263.404	
Total	14653.159	47		

* $p < .05$.

significance. It was concluded that the factor of force exhibited the only significant effect on the accuracy of responding in a coincidence-anticipation task, as measured by constant error.

A posteriori comparison examined the differences of the three levels of force as revealed by the group constant error means of -12.805, -16.401, and -2.111 (refer to Table 2). A Newman-Keuls procedure was the technique used in this analysis; the results are presented in Table 4. The effects of a 50% maximum force exertion resulted in significantly more accurate responses than the NF group or the 25% maximum force group.

Analysis of Variable Error Scores

The variable error score was used as a measure of a subject's consistency over all trials. The VE scores are the standard deviation of the algebraic scores around the constant error. A summary of the mean variable error scores is presented in Table 5. The lowest VE score across all groups was 30.32 msec. and was reported for the males comprising the 50%/5 sec. group. A VE score of 36.46 msec., exhibited by females in the 25%/5 sec. group, was the lowest score reported across all female subjects. The largest VE score of 55.80 msec., exhibited by females in the 50%/15 sec. group, indicated the most variability of responses when compared to all groups. On the average, males were somewhat less variable in their responses than females. The largest difference with regard to the factor of sex was found at the 50% force exertion level.

Table 4

Newman-Keuls Test for Differences among the Mean Constant Error Scores (in milliseconds) for the Three Force Levels

Force Levels		50%	NF	25%
	Means	-2.111	-12.805	-16.401
50%	-2.111	——	-10.794	-14.390 *
NF	-12.805		——	-3.596

* $p < .05$

Table 5

Mean Variable Error Scores in Milliseconds across Factors of Force, Time, and Sex

	Levels of Force	Interval Duration	Male	Female	M for Treatment Condition
		5 sec.	38.840	42.411	
	NF				41.610
		15 sec.	46.383	38.806	
M for Males and Females across Time			42.611	40.608	
		5 sec.	40.750	36.463	
	25%				39.099
		15 sec.	39.620	39.563	
M for Males and Females across Time			40.185	38.013	
		5 sec.	30.325	39.604	
	50%				42.221
		15 sec.	43.152	55.804	
M for Males and Females across Time			36.738	47.704	
		5 sec.	36.638	39.492	38.065
		15 sec.	43.051	44.724	43.888
M Males			39.845		
M Females				42.108	
Grand Mean					40.976

The effects on VE scores of force, time, and sex were determined by an analysis of variance. A summary of results is presented in Table 6. The main effect of force was not significant, as indicated by an F ratio of 0.85. The F ratios for the factors of time and sex were 7.92 and 1.19, respectively. With 1 and 36 degrees of freedom, the F ratio needed for significance at the .05 level of confidence was 4.17; with 2 and 36 degrees of freedom, an F ratio of 3.32 was needed for significance. Consequently, the main effect of time was significant. The interaction of force and time revealed an F ratio of 4.43; this interaction was significant at the .05 level. The force by time interaction suggested that both factors are dependent upon each other in their effect on VE scores. As shown in Figure 4, the profiles for variable error scores for 5 and 15 seconds were similar across the no-force and 25% force levels. This trend, however, did not continue at the 50% force level. The treatment combination of 50%/15 sec. exhibited considerably greater variability than the 50%/5 sec. treatment combination. Therefore, it was concluded that the treatment effect of time was not independent of the effect of force on the consistency of responses as measured by variable error.

The force by sex interaction, represented by an F ratio of 4.42, was also significant. A profile of this interaction is shown in Figure 5. It was concluded that the effects of force and sex were not independent in their effects on variable error scores. The factor of sex was influenced by force, to the greatest degree, at the 50% maximum force exertion level as depicted in Figure 5.

Table 6

Summary of ANOVA across Factors of

Force, Time, and Sex

Source	Sum of Squares	Degrees of Freedom	Mean Squares	*F*
Force	87.622	2	43.811	.85
Time	406.825	1	406.825	7.92*
Sex	61.479	1	61.479	1.19
Force x Time	455.165	2	227.582	4.43*
Force x Sex	454.393	2	227.196	4.42*
Time x Sex	4.185	1	4.185	.08
Force x Time x Sex	149.364	2	74.682	1.45
Subjects within Groups	1846.895	36	51.302	
Total	3465.928	47		

* $p < .05$

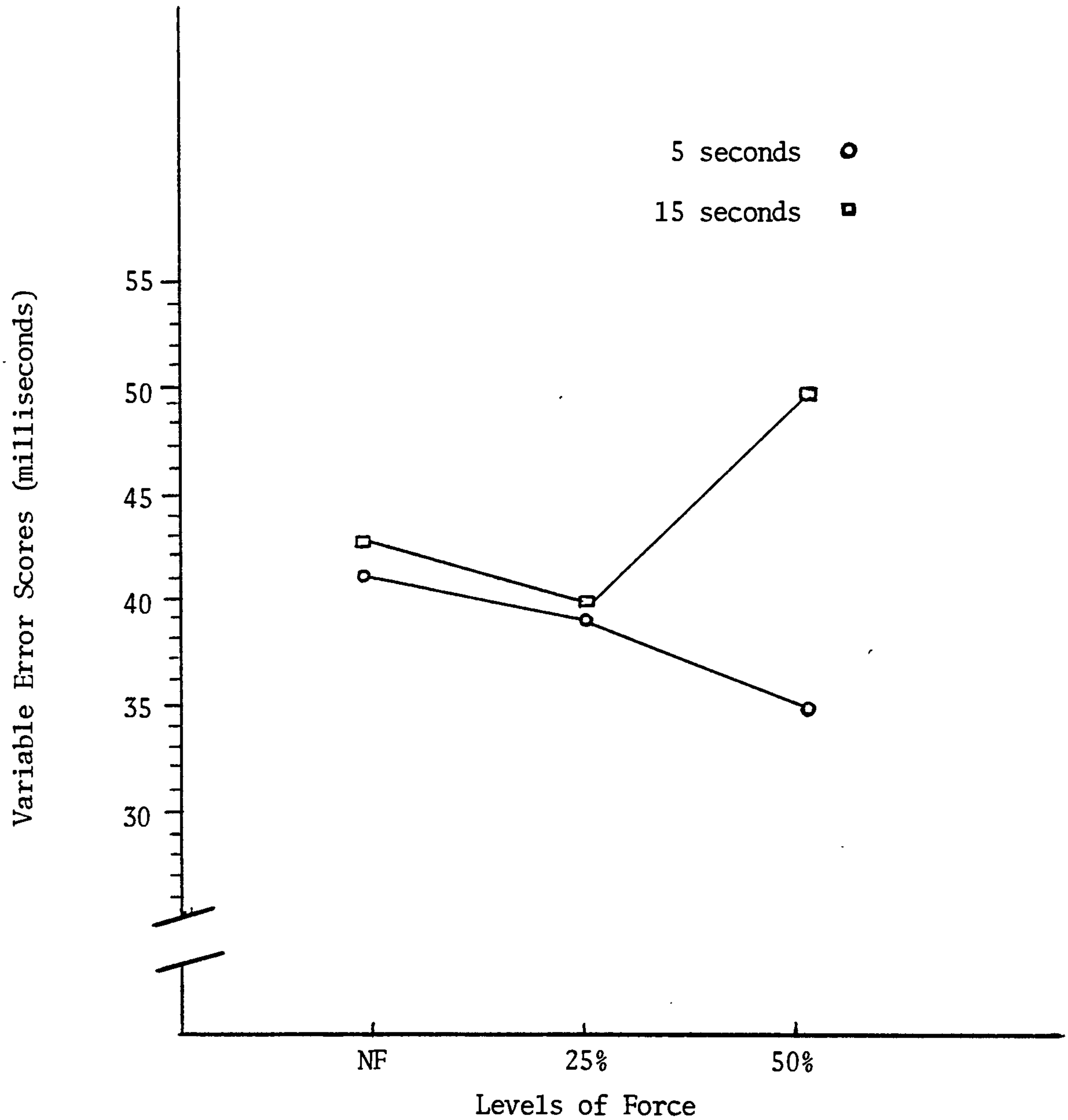

Figure 4

Profile of Force by Time Interaction

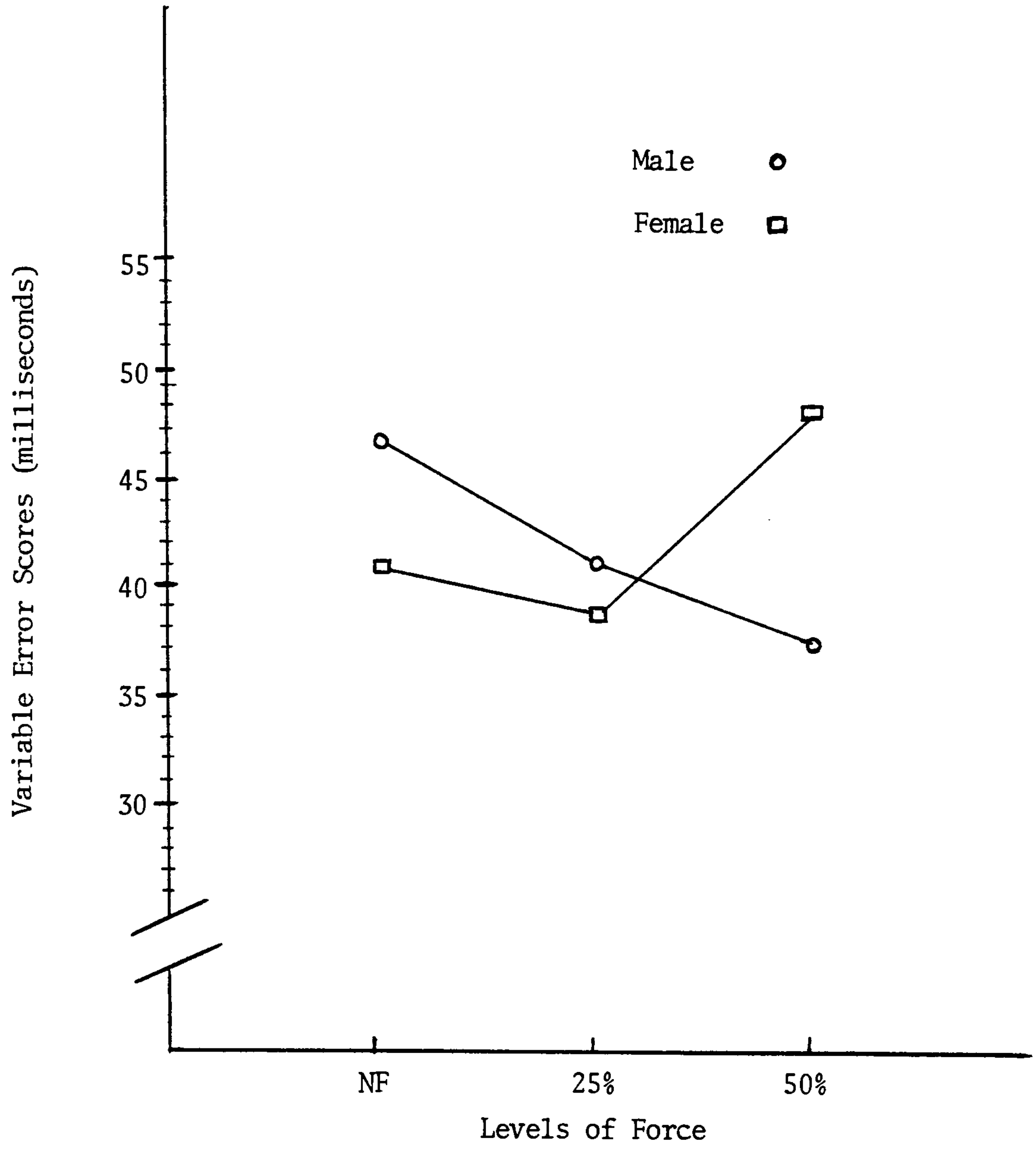

Figure 5

Profile of the Force by Sex Interaction

Summary

The reliability coefficient of .85, determined by an intraclass correlation technique, was found to be an adequate indication of raw score reliability. An analysis of variance determined the effects of the factors of force, time, and sex on constant error scores. With 2 and 36 degrees of freedom, an *F* ratio of 3.32 was needed for significance at the .05 level of confidence. The main effect of force revealed a significant *F* ratio of 3.35; thus, the null hypothesis concerning the effects of varying magnitudes of force exertion on the accuracy of responses was rejected. The results of a Newman-Keuls analysis of the group means for the three levels of force supported the significant difference, revealing that the 50% maximum force group was significantly more accurate in responding than the NF group or the 25% maximum force group. The effects of time and sex on the CE scores were not significant.

An analysis of variance of the VE scores determined that the factor of time had a significant effect on the consistency of responses. The main effects of the factors of force and sex were not significant; however, significant interactions of force by time and force by sex were reported with *F* ratios of 4.42 and 4.43, respectively. It was concluded that the treatment effects of time, and the effect of sex on VE scores, was dependent upon the interaction with the factor of force for significance at the .05 level of confidence.

Chapter 5

DISCUSSION OF RESULTS

This chapter presents a discussion of the results reported in Chapter 4. The topics of discussion are in the following order: reliability, results of constant error analysis, and results of variable error analysis. A summary of the topics concluded the chapter.

Reliability

A reliability coefficient of .85, determined by an intraclass correlation technique, was found for the raw scores of trials one through 40 for all subjects. The coefficient of .85 indicated that the responses were reliable over all trials. The reliability coefficient was in agreement with Slater-Hammel (1960) who reported a correlation of .84 between test days (with KR) and a .95 for KR withdrawal. Belisle (1963) reported a coefficient of .86, and also concluded that it was adequate for measures of coincidence-anticipation. Similar to the Slater-Hammel (1960) study, Belisle (1963) reported a considerably lower reliability coefficient for trials with KR available.

Constant Error

Negative constant error scores indicated that the subjects were early in their anticipation of the arrival of the sequence of lights to the target light. An overall tendency for subjects to develop this anticipatory behavior over practice and with increased experience was in agreement with other investigations of timing ability (Bartlett & Bartlett, 1959; Schmidt, 1967). All groups, excepting the 50%/15 sec. group (both males & females), exhibited early responses.

A constant error for females in the 50%/15 sec. group of 1.35 msec. was comparable to a CE of 2 msec. reported by Belisle (1963). Similarly, the average responses for males at the 50% maximum force level was 1.44 msec. as measured by constant error. An overall CE of -2.111 msec. indicated extreme accuracy in responding by the 50% maximum force exertion group. Slater-Hammel (1960) had reported no systematic error, and as previously noted, Belisle reported only a 2 msec. error rate. Thus, the -2.111 mean constant error value was well within the accepted range of plus or minus 10 msec. to be considered a successful "hit". A reduced error rate or accuracy of responses may be attributed to availability and effective use of KR as discussed by Slater-Hammel (1960) and Belisle (1963). However, Haywood (1975) failed to find significant differences between groups performing without KR and those receiving quantitative or qualitative knowledge of results. The present investigation provided the same KR after each trial to each subject. Therefore, the increased accuracy for the 50% maximum force group could not be attributed to additional feedback from knowledge of results. Rather, the superior accuracy was viewed as a function of the amount of proprioceptive feedback available to the 50% group.

An analysis of variance determined the effects of force, time, and sex on constant error. The factor of sex did not have a significant effect on the accuracy of responses, as measured by constant error. Although a number of studies reported significantly superior performances by males (Dorfman, 1977; Dunham, 1977; Ridenour, 1977), Dorfman (1977) noted that there was a smaller difference between the sexes at the older age classifications. The mean age of the Ithaca College subjects used in this study was 21.2 years, which is a similar maturity level compared to the older age groups of the Dorfman study comprised of 18-19 year olds. The consequence of being exposed to many coincidence-anticipation situations (as adults normally are) in driving and sport environments, is an increased experience in anticipation type tasks. Schmidt (1968) mentioned this "adult experience" effect in a discussion concerning the high degree of accuracy in early trials. Although females were slightly more accurate in the overall responses, as measured by constant error, the difference was not significant. Based on the results of the analysis of the effects of sex on CE scores, the null hypothesis, concerning the effect of sex on the accuracy of coincidence-anticipation ability, was accepted.

The factor of time did not have a significant effect on the accuracy of responses. The five or 15-second interval measured the time between the end of the force exertion task, or "ready" signal for the control groups, to the onset of the warning light. It was concluded that the delay interval had little effect on accurate performances in a coincidence-anticipation task.

A significant effect on CE scores was found for the factor of force. Although a trend for increasing accuracy with increasing force was not evident in the mean constant error scores, the responses of the 50% maximum force exertion group were significantly more accurate than the NF group of the 25% maximum force exertion group. This was in agreement with a study by Quesada and Schmidt (1970) whereby increased accuracy was reported for subjects performing a left-arm feedback task prior to a right-hand timing task. Similarly, using a time estimation task, Parker (1973) reported that the most accurate performances were exhibited by groups performing 50% of their maximum grip strength prior to the timing task. The increase in accuracy at the highest level of force in this investigation (50% max.) supports the concept of increasing muscular tension as an enhancer of performance (Clarke, 1968; Duffy, 1932; Freeman, 1938). The significant effect of force exertion on CE scores led to the rejection of the null hypothesis with regard to the effects of force on the accuracy of coincidence-anticipation ability.

Variable Error

The measure of variable error, the standard deviation of the algebraic scores about the constant error, was an indication of a subject's consistency in responding. A low VE score was interpreted as revealing greater consistency or less variability. The best overall VE scores were exhibited by males in the 50%/5 sec. group, and by females in the 25%/5 sec. group. The most consistent responses were made by males comprising the 50% force exertion group, followed by females of the 25% force exertion group. Although the male subjects revealed a decrease in variability as a function of an increase in force exertion, the VE group means for female subjects revealed a trend towards an inverted U effect as described by Parker (1973). Performance for females was best at the moderate level of force exertion. The results for male subjects tend to agree with those reported by Quesada and Schmidt (1970).

An analysis of variance determined the effects of force, time, and sex on variable error. The main effects of force and sex did not significantly affect VE scores. The factor of time was reported as having a significant effect on variable error; however, the significant interaction of the force and time factors confounded the independent effect of time. In addition, a significant force by sex interaction was reported. Profiles of both interactions can be reviewed in Figures 4 and 5 in Chapter 4.

The force by time interaction is primarily explained by the time-varying proprioceptive trace concept of Adams and Creamer (1962b). As noted earlier, the most consistent group had performed the 50% force exertion task five seconds prior to the timing task. The time-varying proprioceptive trace hypothesis proports that increasing amounts of proprioceptive feedback (PFB), generated by the exertion of force, will be of greatest aid over the shortest time interval. The increase in the proprioceptive activity at the 50% force level, exerted at time "t" was advantageous at time "t +Δt".

The length of the decay interval at the 50% force exertion level revealed the most difference as shown in the interaction profile in Figure 4 of Chapter 4. The most supported view of the force by time interaction is the short-term memory concepts involved in the use of proprioceptive feedback traces (Schmidt, 1971). The greater consistency at the highest force level can be attributed to the short delay from the end of performance to the use of the PFB in the timing task. The rapidly decaying PFB trace was an advantage to the consistency of responses when the force exertion task was performed five seconds prior to the timing task.

A second interaction was reported with regard to the factors of force and sex. The factor of force revealed the greatest influence on the factor of sex at the 50% force exertion level. Whereas the females exhibited the most variability of responses at this level, the males performed the best of all groups at the 50% force exertion level. This contrast of results can be explained by a number of investigations concerned with arousal and activation level. The magnitude of force may have evoked too much activation, or may have been too distracting for the female subjects (Courts, 1942; Duffy, 1957; Parker, 1973). Therefore, the females could not have adequately or consistently utilized the PFB as a guide for the consistency of responses. Furthermore, 50% of the maximum grip strength may have been too disruptive, especially over the 40 trials, thereby eliciting erratic behavior and the reported variability of responses.

It is of interest to note, however, that the group VE mean for females at the 25% force exertion level is quite indicative of more consistent responses. The group mean of 38.013 for females is comparable to the 36.738 msec. exhibited by the males of the 50% force exertion level. It appears that 25% of the female's maximum grip strength, performed prior to the timing task, was an adequate amount of proprioceptive feedback available without being distracting. The 50% of the maximum grip strength for males was apparently an adequate amount of feedback.

The overall VE scores for males decreased as the groups approached the 50% force exertion level. This was in agreement with Quesada and Schmidt (1970). In addition to increased accuracy with increased PFB, they also reported superior within-subjects consistency as a function of increased PFB. Although males did not reveal a tendency toward an inverted-U effect with increasing force levels, it is possible that an increased amount of force, greater than the 50% exertion, would be necessary to generate inconsistent responses in male subjects. An investigation by Parker (1973) reported results to the aforementioned effect. In conclusion, the interaction effects of force and sex can be summarized as a concept of a degree of arousal or activation. The level of arousal enhanced consistency in the responses of male subjects at the 50% force exertion level, and enhanced consistency for females at the 25% force exertion level.

Summary

A reliability coefficient of .85 was considered adequate for the determination of the reliability for all trials. The obtained coefficient was in agreement with Slater-Hammel (1960) and Belisle (1963).

Constant error scores indicated that the subjects exhibited a tendency to respond early in their anticipation trials. The factor of force had a significant effect on constant error, while the factors of time and sex were not significant in their effect on the accuracy of responding. The force effect revealed superior performance by members of the 50% force exertion group. This was in agreement with other studies indicating more accurate performance with greater proprioceptive feedback. The null hypothesis that the performance of a force exertion task prior to the timing task would not significantly affect the accuracy of coincidence-anticipation ability was rejected.

The discussion of variable error emphasized the interactions of the force and time factors and the factors of force and sex. Although the factor of time revealed a significant effect of VE scores, the interaction of force by time was discussed with regard to the time-varying proprioceptive feedback trace suggested by Adams and Creamer (1962a). It was concluded that the increased proprioceptive activity of the 50% force exertion group was an advantage for performance of a task at some later time. The rapidly decaying PFB trace was viewed as a facilitating agent in the consistency of responses when performed at the interval of five seconds prior to the timing task.

The force by sex interaction was discussed with regard to the concepts of activation and arousal when related to muscular tension and force exertion. The males of the largest PFB group performed with the most consistency, while the females in the moderate or 25% force exertion group exhibited the next most accurate scores. It was concluded that the 50% level of force exertion was too distracting and disruptive to the development and use of a suitable proprioceptive trace; however, the 25% force level for female subjects was comparable to similar VE scores as the males in the 50% force exertion group. An inverted-U trend was noted for the female subjects and speculation was made to the possible occurrence of this trend in the event that a 75% force exertion task was required of the male subjects.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to determine the effects of proprioceptive force cues on the accuracy and consistency of anticipatory timing ability. Forty-eight male and female undergraduate and graduate students, enrolled at Ithaca College for the 1978, spring semester volunteered to participate in the study. Eight subjects were randomly assigned to each of the six experimental and control groups. Each group was comprised of four male and four female subjects. A Bassin Timer was used to test timing ability, a Stoelting hand dynamometer measured force exertion. The subjects sat directly in front of the runway apparatus thus allowing the sequence of lights to approach them from a head-on location. The hand dynamometer was placed on the table to the side of the non-dominant hand of the subject.

The subjects in the experimental groups were given two strength trials to determine their maximum grip strength. A value of 25% or 50% of maximum grip strength, depending upon group assignment, was marked on the dynamometer as a reference point for the force exertion task. All subjects in the four treatment groups performed the force exertion task prior to each timing trial. Testing was administered over a 3-day period. Subjects performed 40 trials per day.

The experimenter initiated each trial through verbal cues of "grip" for the treatment groups, and "ready" for the control groups. After the performance of the force task, subjects had a 5- or 15-second delay before the onset of the sequence of lights. The timing task consisted of the release of a telegraph key at a time coincident to the arrival of the light sequence to the target light.

The experimenter gave the subjects knowledge of results in terms of "early", "late", or "on", thus describing the relationship of the response to the arrival of the lights to the target light. Algebraic error scores were recorded for each response about a perfect 0.00 millisecond response; early responses were assigned a negative value, while late responses were recorded as positive. The mean algebraic error reflected the accuracy of the subjects' responses.

An intraclass correlation technique determined the reliability of all raw scores to be acceptable. The effects of force, time, and sex on constant error was determined by an analysis of variance. The effect of force on constant error was found to be significant. The variable error scores, a measure of subjects' consistency, were analyzed with a separate analysis of variance. A significant main effect of time was reported. A significant interaction effect was found for the factors of force and time and, similarly, for the factors of force and sex. The results supported the concept of force as a facilitating agent for accuracy in timing ability;

however, force was not a significant factor in the consistency of responses. Time was found to be significant as an effect on VE but was dependent on the interaction with force.

Conclusions

Within the limitations of this study the following conclusions were made:

1. The performance of a force exertion task has a facilitating effect on the accuracy of responses in a coincidence-anticipation task.

2. The duration of the time interval (5 or 15 seconds) between the conclusion of the force task and the onset of the coincidence-anticipation task does not affect the accuracy of responding.

3. Sex is not a significant factor with regard to a subject's accuracy in responding.

4. Neither the performance of a force task nor the magnitude of exertion has a significant effect on the variability of subjects' responses.

5. The duration of the time interval (5 or 15 seconds) has a significant effect on consistency of responding but is dependent upon the factor of force.

6. Females exhibit more variability than males, especially at the 50% force level, in their responses to an anticipatory timing task.

Recommendations

From the results of this study the following recommendations are made:

1. A study to investigate the transfer effect of practice with proprioceptive feedback and without proprioceptive feedback should be conducted.

2. A similar study should be conducted to determine the effect of a variety of speeds for the sequence of lights on the accuracy and consistency of responses.

3. A similar study should be conducted requiring the subject to exert an amount of force throughout the timing task as an investigation of the input hypothesis.

APPENDICES

APPENDIX A

Results of Pilot Study Conducted

February 1978

Speed of Light Sequence	Delay Period	Group Means (Error Scores) Day 1	Day 2 (in seconds)	Grand Mean
5 mph	5 sec.	.015	-.007	.008
8 mph	5 sec.	.034	-.012	.011
10 mph	5 sec.	-.008	-.009	-.008
10 mph	5-6.5 sec.	.007	-.004	.005

APPENDIX B

INFORMED CONSENT FORM

The purpose of the investigation is to study the effects of varying degrees of force on the facilitation of the timing involved in the ability to anticipate.

1. Testing will involve 3 sessions. (One session per day)
2. Each session will be 15-20 minutes in length. (Except the first session of 30 minutes)
3. You will be required to release a telegraph key; and depending upon your group assignment, you will also be required to exert a designated amount of force using a hand dynamometer.
4. Since you have volunteered to participate in the experiment, you are free to withdraw consent and discontinue participation at any time if you so desire.
5. The experimenter will answer any questions concerning procedures during the instructional phase of the testing.

Thank you for your time and cooperation.

Signature______________________________ Date__________________

APPENDIX C

Instructions to Subjects (Control Groups)

The purpose of this study is to determine your anticipation of the illumination of the last of a series of lights. Before you is a track that contains a row of lights that will be illuminated in a sequence from top to bottom. In the actual testing conditions, the overhead lights in the room containing the track will be extinguished. Directly in front of you is a telegraph key. When the experimenter says "depress", place the index and middle fingers of your dominant hand on the telegraph key and depress. Hold the telegraph key in the depressed position. After you depress the key, fix your vision in the direction of the track. A yellow warning light at the farthest end of the runway will alert you to the start of the sequence of lights. It is important that you pay attention to this warning signal, as there will be no further signals prior to the sequence of lights. Your task is to anticipate the illumination of the last light, the target light, and to release the telegraph key by extending the wrist so that you have your fingers removed at the instant the last light is illuminated. After your response, the experimenter will tell you if you have responded "early" or "late". "Early" indicates that you have responded before the arrival of the lights to the target light; "late" indicates that you have responded after the light sequence reached the target light. If you anticipate the exact arrival of the sequence of lights to the target light, the experimenter will say "on". No other information will be given. You may relax until the experimenter again says "depress", which is your cue to depress the key to start the next trial. A summary of your procedure is as follows: (a) you will depress the telegraph key upon the command by the experimenter; (b) you will hold the key in a depressed position until you anticipate the illumination of the last light (target light); (c) you will release the key at the instant the last light is illuminated; (d) you will receive knowledge of results, and relax until the experimenter again says "depress".

Are there any questions?

Instructions to Subjects (Experimental Groups)

The purpose of this study is to determine your anticipation of the illumination of the last of a series of lights. Before you is a track that contains a row of lights that will be illuminated in a sequence from top to bottom. In the actual testing conditions, the overhead lights in the room containing the track will be extinguished. You have been randomly assigned to the group that will perform a force exertion task prior to each trial. The dynamometer, positioned on the table, will be used for the force exertion task. The procedure will be as follows: (a) at the start of each trial the experimenter will way "grip", which is your cue to grasp the dynamometer. (b) The experimenter will then say "exert", which is your cue to exert the amount of pressure marked off on the apparatus. It is important that you exert the force in a consistent manner. (c) The experimenter will then say "release", which is your cue to relax your hand, and depress the telegraph key with your index and second finger of your dominant hand. Hold the telegraph key in a depressed position. After you depress the key, fix your vision in the direction of the track. A yellow warning light at the farthest end of the runway will alert you to the start of the sequence of lights. It is important that you pay attention to this warning signal, as there will be no further signals prior to the sequence of lights. Your task is to anticipate the illumination of the last light, the target light, and to release the telegraph key by extending the wrist so that you have your fingers removed at the instant the last light is illuminated. After your response, the experimenter will say "early" or "late". "Early" indicates that you have responded before the arrival of the lights to the target light; "late" indicates that you have responded after the light sequence reached the target light. If you anticipate the exact arrival of the sequence of lights to the target light, the experimenter will say "on". No other information will be given. You may relax until the experimenter again says "grip", which is your cue to grasp the dynamometer to start the next trial. A summary of your procedure is as follows: you will "grip", "exert", and "depress" upon command by the experimenter. You will then release the key at the instant the last light is illuminated. The experimenter will give you knowledge of your response, and you may relax until the experimenter again says "grip", which is your cue to begin the next trial. You should use the feelings produced by the tension of the force exertion to aid in the anticipation task.

Are there any questions?

APPENDIX D

Results of All Subjects' Responses

Results of all subjects' responses on the third day of testing are coded in the following manner: (a) the first number of the identifying code number is the level of force (NF = 1, 25% = 2, 50% = 3); (b) the second number designates the time interval (5 sec. = 1, 15 sec. = 2); (c) the third number describes the sex of the subject (male = 1, female = 2); (d) the fourth number identifies the subject per group; (e) the remaining three numbers were used as an aid to the researcher.

1111311	-023	+016	+031	-022	-035	-020	+058	+030	-032	-062
1111312	-056	-084	-042	+015	-043	-072	-053	-055	-037	-005
1111321	-030	+075	-001	+006	-004	-057	+109	+047	+004	-006
1111322	-021	-041	+006	-020	-011	+054	-013	-019	-015	+134
1112311	+025	-023	-016	-034	-038	+056	-006	-008	+017	+035
1112312	+070	+015	+023	+022	-019	-032	-033	-016	+006	-011
1112321	-063	-081	+002	+084	-023	-055	-008	+019	-033	-006
1112322	-002	-006	-011	-037	-055	-029	-018	-007	-065	-056
1113311	-023	+057	+009	+032	-067	-020	+004	-041	-067	-008
1113312	-028	-009	+009	-014	+006	-032	-032	-015	+020	+037
1113321	-002	+016	-010	+023	+016	+010	+005	+025	+017	-036
1113322	-010	+077	-050	+018	+057	-016	+033	+059	-041	-017
1114311	-046	+082	-057	-032	-010	-035	+037	-090	-039	-057
1114312	-042	-016	-088	-055	+034	-079	-058	-048	+014	-032
1114321	-046	-030	+019	-061	-073	-035	-002	-049	-054	+013
1114322	+010	-050	+014	-029	-041	+043	+028	-091	-055	-001
1121311	-053	-064	-037	+102	-042	-053	-089	-052	-023	-045
1121312	-054	-058	-047	+200	-038	+051	+017	-020	-022	-016
1121321	-040	-033	+029	-029	-004	-056	-033	+135	-051	-020
1121322	+012	-038	-039	-065	-031	+001	+025	-020	-044	-046
1122311	-043	-070	-019	-013	-032	-038	+038	-069	+042	-062
1122312	+041	-073	+026	-068	-050	-040	-006	-047	-029	-038
1122321	+028	-019	-105	-076	-026	-019	-082	+013	-006	-098
1122322	-014	-034	-067	-061	-008	-003	+044	-026	-079	-007
1123311	+091	+025	+079	-040	+065	-004	+063	+015	+063	+033
1123312	-024	+000	+056	+051	+056	+049	+046	-017	+004	+032
1123321	+032	+070	-013	-029	+023	-047	+006	+000	+068	-001
1123322	+005	-016	+012	+001	+018	+027	-009	-019	-023	-049
1124311	-063	-053	-036	-075	-044	-052	-085	+002	-073	-065
1124312	-078	-067	-032	-064	-049	-024	-075	-074	+059	-035
1124321	-073	-059	+005	-075	-077	-040	-049	+049	-081	-064
1124322	-074	+083	-032	-076	-063	-077	-044	-039	-042	-057
1211311	+036	-068	-013	+063	-068	+096	-045	-055	-038	-064
1211312	+114	-052	+033	-043	+067	-011	+041	-068	-038	+030
1211321	-055	-025	-037	-035	-022	-020	+037	-052	-016	-031
1211322	-066	-045	-039	-039	+044	-042	-030	-054	-040	+032
1212311	-028	+034	-003	-031	-035	-040	-037	-019	-002	-021
1212312	-072	-040	-020	+029	-062	-052	-034	-040	-016	-016
1212321	+028	+012	-059	+019	-002	+082	+066	+003	+072	+067
1212322	+034	+018	+047	+023	+036	-016	+043	+062	-040	+003
1213311	+064	+061	+022	-014	-041	+034	+066	-055	+049	+033
1213312	+074	-025	+073	+097	-061	+003	-009	+022	-016	+049
1213321	+014	-035	-052	-031	+042	-037	+013	-042	-006	-040
1213322	-017	-043	+003	+034	-034	-009	-052	-050	-037	-066
1214311	-089	+064	-071	-084	-038	-068	+087	-086	-036	-063
1214312	-057	+122	-071	-086	-048	-040	-015	-025	-093	-024
1214321	-033	-077	-064	-094	-008	+073	-025	-069	-091	-044
1214322	-062	+051	-041	-007	-045	-043	+000	-053	-045	-049
1221311	+043	-035	-013	+088	-023	-035	-001	+003	-014	+025
1221312	+019	-059	-040	+026	-035	+009	+002	-041	-023	+034
1221321	+029	-020	+009	-025	+013	-010	-028	-008	-054	-009
1221322	-017	+062	-007	+003	-001	-012	+059	-019	+015	-008
1222311	-046	-025	-016	-015	-055	+013	-012	+054	-008	-060
1222312	-030	-010	-050	-075	+055	-042	-032	-072	-050	-062
1222321	-044	-006	-052	+068	-037	-045	+022	-029	-065	-021
1222322	-066	-040	-055	-040	+010	+000	-005	+039	-055	-056
1223311	-032	+010	+023	-002	+039	+048	-008	+013	+027	-061
1223312	+044	+010	+042	-050	+052	+009	-061	+018	+017	-008
1223321	+054	+008	-010	+069	-058	-001	+026	-038	-031	+006
1223322	+112	-064	+019	-020	-035	+074	+042	-048	+009	-050
1224311	+040	-012	-007	-010	+019	-077	+080	-084	-024	-027
1224312	-036	-060	+081	-063	+058	-066	-043	+024	+022	+004
1224321	-008	+025	+059	-057	-039	-043	-047	+021	+034	+049
1224322	-033	-075	+061	-022	+005	+023	+040	+008	+016	-016

2111311	-034	+049	-027	+093	-067	-042	-024	-028	-040	-048
2111312	-037	+036	-020	-066	-032	-056	-051	-030	-018	-037
2111321	+021	+000	-057	+053	+012	-056	-027	+084	-008	-033
2111322	-041	-040	-032	+005	-004	-034	+002	-023	-002	-024
2112311	-010	-044	-024	+023	+036	-038	-031	-053	-056	+002
2112312	+008	-056	-073	-065	+036	+064	-071	-040	-043	-033
2112321	-084	-057	-062	-072	-024	-031	-027	-054	-028	-020
2112322	-059	-058	+041	-086	-018	+014	-049	-043	-011	-062
2113311	-038	-049	-008	-062	-092	-054	-024	-104	-069	-018
2113312	-051	+067	-092	-015	-087	-039	-057	+019	-033	-007
2113321	-089	-046	-043	-081	-117	-082	-014	+058	+028	-044
2113322	+121	-016	-081	-018	-061	-058	-041	-099	-024	-091
2114311	-060	-005	-045	-083	+021	-037	+044	-043	-017	+010
2114312	-079	+001	-041	-045	-061	-075	-094	+028	-042	-040
2114321	-038	-019	+083	+015	-054	-003	-007	-044	-034	-057
2114322	+007	+017	+065	+047	-017	-042	-041	-012	-053	-055
2121311	+024	+047	-060	-032	+006	-017	+160	-035	+044	-085
2121312	-014	-062	-001	+033	-033	+016	+022	-036	-045	+023
2121321	-014	+024	+010	-029	-009	+067	+018	-032	-044	+053
2121322	+022	-010	-048	+037	-004	+021	+019	+055	-030	+019
2122311	-059	-006	-048	-046	-058	+034	-041	-069	-031	-038
2122312	-005	+000	+033	-086	-005	-067	+011	-054	-038	-025
2122321	-018	+005	-063	+048	-028	-049	-046	-026	+042	-027
2122322	-039	-027	-020	-020	-041	+015	-039	-012	+046	-024
2123311	-004	+002	+006	-029	-024	+053	+056	+037	+004	+003
2123312	-038	+022	+032	-042	+003	-010	-018	+110	+002	+057
2123321	+054	+090	+060	+018	+023	-025	-042	+047	+020	-010
2123322	-013	-012	+028	+079	-034	+028	+030	-075	+023	+015
2124311	+033	+025	-040	-024	-050	-015	-048	-054	-005	+024
2124312	-023	-005	-031	+025	-008	+026	-017	-050	-036	+024
2124321	-048	+002	+041	+000	+016	-016	+010	+002	-011	+056
2124322	-065	+014	-011	+014	+015	-014	-021	+042	-007	+011
2211311	-044	-077	-095	-107	-044	-066	-037	-008	-049	-083
2211312	-065	-058	-017	-070	-048	-058	-031	-079	-042	+010
2211321	-030	-053	+037	+010	-048	+022	-087	-070	+028	-073
2211322	-033	+077	-025	+057	-022	-058	-043	+022	+103	-063
2212311	-039	-071	-023	-058	+056	-051	+032	-024	+076	-044
2212312	-012	+012	-073	-031	-015	-034	-100	+041	-023	-007
2212321	+022	-016	-006	+023	+013	-116	-037	-009	-022	+034
2212322	-031	+002	-012	+042	-023	-003	-058	+012	-023	-002
2213311	+023	+005	-022	-031	+054	-032	-010	-010	-050	-026
2213312	-007	-021	-036	-042	-013	-055	-038	-028	-034	-009
2213321	-024	-052	-068	-027	-009	+001	-042	-053	-031	-045
2213322	-068	-065	-042	-069	-024	-007	-006	-064	-052	-022
2214311	-033	-036	+034	-048	-036	-058	-056	-033	-046	+007
2214312	+077	+015	-061	-041	+052	-056	+057	-064	+002	+078
2214321	+106	-007	+084	-031	+032	-022	-008	-016	+022	+076
2214322	-012	-055	-027	+079	-018	-023	+023	+002	+002	-005
2221311	-113	+005	+010	-032	+033	-017	-011	+015	+007	-023
2221312	-031	-085	+058	+024	+004	+037	-007	+008	-022	+048
2221321	-008	-022	-038	+075	-047	-035	+013	+014	-029	-059
2221322	-044	-029	+062	-093	+021	+034	-103	+016	-031	-072
2222311	+023	-042	+000	-053	-038	+021	-031	-018	-016	-030
2222312	+004	-083	+020	+010	-027	-061	-040	-044	+009	+015
2222321	+025	-051	+028	-083	-032	-063	+004	-034	-074	-003
2222322	-073	-030	-085	-014	-094	-061	+035	-067	-009	-007
2223311	-004	-015	+029	-033	-044	+021	+001	-019	-018	+046
2223312	+039	-004	-025	+006	-006	+014	+048	-053	-046	+034
2223321	-050	+080	+018	-016	-029	-006	-044	-018	-038	+035
2223322	+032	-033	+035	-006	-043	-008	+016	-010	+014	-024
2224311	+052	-071	-064	-074	-095	+006	-013	-102	-045	-053
2224312	+017	-039	+011	-064	+052	+014	-033	+052	-008	+037
2224321	+012	-016	-025	-054	+035	-033	-032	-012	-049	-062
2224322	+015	+011	+054	+020	+022	-067	+059	-050	+002	+073

3111311	+033	-032	-004	-040	+109	-035	-034	+045	-016	+061
3111312	+041	+020	-036	-011	+029	-020	-018	+035	-044	+035
3111321	+007	-006	-006	+023	+008	+044	+011	+018	+031	+015
3111322	-036	-009	-008	-022	-033	+041	+090	-010	-002	-003
3112311	-033	+034	+006	-033	-003	-040	-029	-056	-040	-031
3112312	-040	+001	+011	-080	-020	-074	-081	-070	-032	+013
3112321	-090	-038	-051	-056	-012	-070	-060	-024	-071	-037
3112322	-038	-039	-043	-033	-038	-044	-038	-079	-048	-024
3113311	-037	-022	+026	-030	-027	+005	+011	-009	+015	-011
3113312	+004	+031	+043	+010	+009	+034	+041	+020	+026	+002
3113321	-002	-022	+020	+028	+005	+010	+031	+000	+000	+003
3113322	+001	-009	+003	-023	+019	-010	+000	-006	+006	+001
3114311	-051	+058	-066	-084	+024	-009	-041	-041	-046	-039
3114312	-030	-023	-012	-015	-035	-044	-018	+010	-007	+022
3114321	-059	-044	+096	-013	-013	-055	-056	-016	-020	+058
3114322	+031	-074	-030	+053	+025	-048	-041	-012	-048	-043
3121311	-070	-033	+026	-057	-025	+007	+026	-022	-026	-012
3121312	-036	-018	-036	-053	-008	-001	-046	+009	+069	+029
3121321	-013	-067	+009	-048	-010	-036	+003	-047	-027	-028
3121322	-046	+046	-016	+023	-039	-028	-033	-014	-031	-057
3122311	-043	+144	-035	+007	-042	-054	-012	-046	-031	-052
3122312	+057	+038	-047	-009	+018	-038	+034	-025	+009	+035
3122321	-012	-033	+079	-053	+066	-016	+022	+069	-045	+010
3122322	+049	-054	-041	-027	-001	+013	-015	-048	+025	-004
3123311	-022	-076	+071	-081	-022	+049	+025	-048	+049	-007
3123312	-017	-035	-042	-036	-052	+014	+028	-078	+014	+004
3123321	-076	-016	-037	+048	-061	-048	-046	-021	-049	+026
3123322	-064	-079	+021	-040	-019	-050	-049	-031	-077	-063
3124311	-036	-061	+061	-016	-016	-038	+010	-042	-055	-047
3124312	-053	-042	+068	-041	-015	+040	-051	+049	+026	-047
3124321	+026	+009	+040	-024	+050	-006	-044	+062	+045	+015
3124322	+030	-060	+056	+010	-024	+057	-031	+020	-011	-053
3211311	+063	+019	-023	-003	+051	+046	+005	-059	+091	+054
3211312	+111	-037	+088	+051	+027	+093	-026	+045	-027	+090
3211321	+074	+066	+071	+101	+087	+069	+136	-072	-010	+029
3211322	-034	+106	+068	+014	+031	+018	+002	+050	+039	+042
3212311	+019	+096	-070	+037	+065	-076	+029	-043	+011	+022
3212312	-043	-033	-023	-017	-012	+045	-009	-006	+019	-026
3212321	+041	-055	-020	-039	+122	-079	-020	-012	-015	-048
3212322	+045	-026	+022	-065	-098	-021	-027	-047	-032	-021
3213311	+052	+049	+033	+071	+043	-007	+003	-044	+034	+037
3213312	-007	+047	+034	+082	+052	+068	-008	+074	+021	+039
3213311	+029	-001	+040	-083	-017	+045	-002	-065	-027	+027
3213322	+040	+037	-004	+037	+043	+017	+030	-018	+019	-012
3214311	-014	-005	-013	-009	+098	-055	+006	-026	-041	+008
3214312	+001	+027	+041	+008	-032	+043	+014	-007	+024	+028
3214321	-035	+001	+078	-057	-094	+056	-050	+066	-036	+076
3214322	-012	+027	+039	-007	+059	+047	+008	-009	+063	+006
3221311	-078	+052	-059	-037	+084	+034	-015	-058	-074	-029
3221312	+027	-095	-015	+027	+019	-018	+094	+098	-055	+090
3221321	+061	+111	+050	+030	+007	-009	+027	-040	+027	+024
3221322	+000	-013	+052	+067	-029	+040	+004	-021	-013	+004
3222311	-094	+015	-101	-075	-016	-056	-099	-031	+100	-067
3222312	-053	+050	-032	-013	-031	-013	-014	-034	+025	+049
3222321	+020	-067	+048	+007	-039	-010	-045	-038	+027	-049
3222322	-087	+119	+065	-044	+254	-063	+086	-041	+027	-029
3223311	-076	+035	-079	-043	-079	+069	-063	+068	-088	-052
3223312	+100	-047	+016	+085	+073	-055	+083	+088	+117	+014
3223321	-065	+001	+057	-062	+001	+064	+035	+060	+071	-014
3223322	+060	-002	-030	-009	+045	-042	+032	+063	+008	-017
3224311	+053	+038	-026	-060	-066	-063	-063	-073	+084	+049
3224312	-067	+085	-065	-031	+001	-065	+004	+027	-064	+014
3224321	+055	-043	+013	+001	+021	+039	+006	+041	-002	+038
3224322	-017	-029	+024	-057	-009	-035	+039	-050	+024	-007

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