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I am submitting herewith a dissertation written by Margaret Ellen Wooddy entitled "Reaction Time and Coincidence Anticipation Performance of Retarded and Nonretarded Subjects." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

Craig A. Wrisberg

Craig A. Wrisberg, Major Professor

We have read this dissertation and recommend its acceptance:

Patricia A. Beitel

H. Allan Lasater

Wendell Liemohn

Accepted for the Council:

CW Minkel

The Graduate School

# REACTION TIME AND COINCIDENCE ANTICIPATION PERFORMANCE OF RETARDED AND NONRETARDED SUBJECTS

A Dissertation

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Degree

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Margaret Ellen Wooddy

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## ABSTRACT

The purpose of this study was to examine reaction time (RT) and coincidence anticipation (CA) performance across an age range of 7-20 years for retarded and nonretarded subjects. An attempt was made to determine whether one or all of the following existed: (a) a developmental pattern of decreasing RT and decreasing CA error scores with increasing age, (b) similar RT and CA performance for retarded and nonretarded subjects at each age level, and (c) a significant relationship between RT and CA performance for any of the various age and IQ combinations.

Eighty male subjects were selected from one of two populations: (a) retarded (IQ range of 50-69, inclusive) and (b) nonretarded. Twenty trials were administered to all subjects on both a simple visual reaction time task and the Bassin Anticipation Timer. Variable foreperiods were randomly assigned to RT trials and a stimulus velocity of 134 cm/sec (1.7 sec, viewing time) was used for the CA trials. Dependent measures (calculated on the data from trials 7-16 on each task) were median RT and median constant error (CE), and variable error (VE) which was the standard deviation of a subject's CE scores around his median CE. The Kruskal-Wallis one-way analysis of variance was used to test for significant differences; and, the Mann-Whitney-Wilcoxen technique was performed, where appropriate, to locate the source of those differences. The Spearman rank correlation procedure was used to determine the strength of relationship between RT and the absolute value of median CE scores.

The results suggested that (a) RT decreases over age for both nonretarded and retarded subjects, (b) the slower RT of retarded subjects when compared with that of nonretarded subjects is more pronounced at younger ages (7, 9, 11 year olds), (c) both retarded and nonretarded subjects demonstrate a slight positive CE bias (i.e., late response) in CA performance, (d) VE decreases over age for both nonretarded and retarded subjects, (e) except for the oldest non-retarded group, there is no significant relationship between RT and CA performance.

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# CHAPTER I

## INTRODUCTION

A major factor in the growth and development of an individual is proficiency in motor skills (Bruininks, 1974). For proficient movement, task demands require effective utilization and appropriate integration of certain motor components. Adaptations and adjustments in performance for mature and experienced performers seem to be automatic; however, those same adaptations and adjustments necessary to skilled performance appear to be lacking in the immature and inexperienced individual. The nonretarded individual appears to be increasingly adaptable to task demands during progressive stages of growth and development (Gesell, 1946; Kay, 1969). Adaptation in motor skills for the retarded individual is important not only in sports skills, but in every aspect of life (Bruininks, 1974).

Much of the inconsistency of skilled performance in children can be attributed to failure to accurately anticipate certain related outcomes which are involved in a particular movement. As the child grows older, this ability to anticipate and effectively predict movement outcomes improves (Wade, 1976; 1980). Smooth and efficient movement in tasks which require the individual to respond to some external event is demonstrated by those performers who exhibit improved timing ability (Schmidt, 1968).

Adaptation in motor performance is frequently affected by the speed with which the person responds to the demands of the task.

Retarded individuals are not able to process information rapidly and respond in an appropriate manner, and are at a distinct disadvantage when compared with those who are faster processors (Baumeister & Kellas, 1968c). Similarly, children have difficulty adapting to the task when there is a demand for a rapid response. They can process a great deal of information, but have difficulty when required to process that information rapidly (Connolly, 1970; Williams, 1974).

## Statement of the Problem

The purpose of the present study was to examine a possible relationship between reaction time and coincidence anticipation across five age categories of retarded and nonretarded subjects: (a) 7-8 years, (b) 9-10 years, (c) 11-12 years, (d) 13-14 years, and (e) 17-20 years. In addition, an attempt was made to determine whether one or all of the following existed: (a) a developmental pattern of decreasing reaction time and decreasing coincidence anticipation error scores with increasing age for both retarded and nonretarded samples, and (b) similarity in reaction time and coincidence anticipation performance between retarded and nonretarded samples at each age level.

For the purpose of the present study, the following hypotheses were tested:

1. There will be no significant difference in the median reaction time scores among age categories within either group: (a) retarded or (b) nonretarded.

2. There will be no significant difference in the coincidence anticipation performance (CE and VE) among age categories within either group: (a) retarded, or (b) nonretarded.
3. There will be no significant difference in the median reaction time scores of retarded and nonretarded groups for any of the five age categories.
4. There will be no significant difference in the coincidence anticipation performances (CE and VE) of retarded and non-retarded groups for any of the five age categories.
5. There will be no significant relationship between median reaction time scores and the absolute value of median CE scores for any age category within either group: (a) retarded, or (b) nonretarded.

## Delimitations

The present study was delimited in the following ways:

1. The samples were from Knoxville, Tennessee, and surrounding areas.
2. The subjects in the samples were males.
3. The samples were drawn from an age range of 7 years to 20 years of age.
4. Subjects in the retarded group had an IQ range of 50-69, inclusive.
5. The IQ scores of the nonretarded subjects were not known.

## Assumptions

The conduct of the present study was made with the following assumptions:

1. The instrumentation was valid for the measurement of reaction time and coincidence anticipation performance.
2. The subjects were naive to each task.
3. All subjects were able to comprehend the requirements of each task.
4. Each subject performed each task to the best of his ability.

## Definitions

For purposes of the present study, the following definitions were accepted.

Apparent motion. A sequential pattern of events which is perceived as motion, but which is in fact an illusion of motion. In the present study, apparent motion was produced by the sequential illumination of separate lamps on the Bassin Timer trackway.

Coincidence anticipation. A component of motor skills in which the subject anticipates and predicts the moment of arrival of a moving stimulus at a predetermined target and makes a response simultaneous with the arrival of the stimulus at that target (Poulton, 1957; Schmidt, 1975). In this study coincidence anticipation ability was demonstrated by the subject as he attempted to depress a response key simultaneously with the illumination of the end light in a series of lights on a trackway. The error measures obtained were median constant error (for a block of 10 trials) and variable error.

Constant error (CE). An error score which describes the bias of the subject's response in terms of direction and distance. It is also referred to as algebraic error (Schmidt, 1975). In this study, CE was the difference (in msec) between the time at which the stimulus reached the target light on the trackway and the time at which the subject depressed the response key. A negative CE score indicated an early response, and a positive error score indicated a late response.

Nonretarded subject. A person who has not been placed in a special education class by the school system in which he is enrolled.

Reaction time. The temporal interval between the presentation of an unanticipated stimulus and the initiation of movement in response to that stimulus (Schmidt, 1975). In this study, reaction time was the temporal interval between the presentation of the stimulus light and the release of the response key.

Retarded subject. A person who has been evaluated by individual psychological testing and determined to have an IQ score which is between 50 and 69, inclusive.

Stimulus duration. The total exact time during which a stimulus event occurs. In this study, the continuous exposure of apparent motion of light sequence on the coincidence anticipation task (lasting 1.7 sec) represented the stimulus duration.

Stimulus velocity. The rate of change in the position of a moving stimulus. It relates the distance which the stimulus travels within a certain amount of time. In the present study, 134 cm/sec was used as the stimulus velocity on the coincidence anticipation task.

## Significance of the Study

Two timing abilities, (a) reaction time and (b) coincidence anticipation, seem to improve with age (Eckert & Eichorn, 1977; Thomas, Gallagher, & Purvis, 1981; Wade, 1980). It has been reported that efficient adjustment to reaction time demands occurs at about age 14 for nonretarded individuals (Eckert & Eichorn, 1977). However, developmental trends of this type have not been reported for retarded subjects. Neither the extent to which coincidence anticipation timing abilities improve nor the point in the developmental process at which this ability improves has been established for retarded or nonretarded persons (Wade, 1980).

Schmidt (1968) commented that past research had been primarily concerned with reaction time; thus neglecting the aspect of coincidence anticipation. There has been limited research which has investigated the possibility of a relationship between these two components, both of which are incorporated in many motor skills. Recently, Thomas et al. (1981) reported evidence suggesting that such a relationship does exist in nonretarded males (ages 7, 9, and 11); however, they and others have reported that this relationship diminishes as age increases for nonretarded individuals (Grose, 1967; Haywood, 1977; Thomas et al., 1981).

Task demands of both coincidence anticipation and reaction time tasks appear to represent different phases of the information processing model (Thomas et al., 1981). Coincidence anticipation involves three phases of processing: (a) encoding stimuli, (b) creating a response plan, and (c) response execution (Rothstein, 1977; Thomas et al., 1981); while reaction time primarily represents the decision making phase of processing (Marteniuk, 1976).

Research has revealed that older children and adults are more efficient information processors in a motor task than are young children (Gallagher & Thomas, 1980; Haith, Morrison, & Sheingold, 1970). In comparison with nonretarded individuals, retarded individuals historically have demonstrated an inability to process information in a motor task (Nettleback & Brewer, 1981).

The present study was designed to investigate age-related similarities/differences between and within nonretarded and retarded groups on two motor tasks, reaction time and coincidence anticipation. In this way the information processing capabilities of these groups were examined.

# CHAPTER II

# REVIEW OF THE LITERATURE

The complex ability of regulating the spatial/temporal characteristics of one's motor behavior is demonstrated in various aspects of motor performance. Presented in this chapter is a review of studies dealing with the information processing capabilities of retarded and nonretarded children and adults. This is followed by a discussion of the literature which deals with timing ability. This discussion is limited to the basic components of (a) reaction time and (b) coincidence anticipation. Within each section, results from studies investigating the performance of nonretarded and retarded groups are reported. Finally, studies suggesting a possible relationship between reaction time and coincidence anticipation are presented.

## Information Processing Capabilities

The theory of information processing has provided an attractive and workable framework for the systematic study of mental events. This theory has also enabled researchers to investigate individual differences which are inherent in mental abilities. Nettleback and Brewer (1981) have suggested that cognitive events may be inferred to occur between the onset of a stimulus and the initiation of the response which follows the stimulus. By partitioning out such events it might be possible to understand the person and his/her cognitive function in regard to selection, transformation, and retention of information.

Nonretarded children and adults. In recent years, some authorities have utilized information processing theory to explain limitations imposed upon perceptual-motor performance (Wade, 1976). Gallagher and Thomas (1980) conducted a study in which subjects in three age groups (7, 11, and 20 years) participated. They used a linear positioning task in which the subject, upon a given signal, was required to make a 40 cm movement within a time of 400 msec. After the completion of the movement the subject was given knowledge of results followed by intervals of 3, 9, or 12 sec (termed the post KR interval). In this way, control was exercised over the movement time and the time between the completion of the last response and the initiation of the next response (inter-response interval). More importantly, this design enabled control of the amount of time the subject had to process knowledge of results. Knowledge of results (KR) informed the subject of (a) directional error (too fast or too slow) and (b) distance error which indicated to the subject errors in the length of his/her response. They reported that as the age of the subject increased the number of errors decreased. Also, as the post-KR interval was lengthened, the error score of the youngest age group decreased. Gallagher and Thomas (1980) concluded that if the child is given enough time following the administration of KR he/she can process the information as well as an adult on this task. They suggested that a reduction in the child's available processing time normally resulted in ineffective use of three control processes of memory: (a) speed of encoding, (b) rehearsal, and (c) recoding.

There is general support for the notion that, in order to perform a task with regularity and consistency, the individual must adopt some kind of strategy (Schmidt, 1968). Rothstein (1977) has suggested that the young child learns separate skills and, for the most part, can perform these skills efficiently. When the young child (5 to 6 years) must integrate these skills in learning a new task, he/she experiences difficulty because he/she must employ new strategies. It has been suggested that the performance of young children indicates that they pursue a strategy which directs attention to all stimuli, whether some of the stimuli are relevant or not (Rothstein, 1977).

Patterson and Mischel (1975) have additionally contended that children (4 years, 0 months to 5 years, 7 months) will attend to relevant stimuli and resist irrelevant stimuli if assisted in the formulation of strategies which enable the individual to attend exclusively to relevant stimuli. They found that the time in which subjects in their study were able to perform the experimental task, a paper and pencil task accompanied by an intermittent attractive distraction, was reduced when the children were given directions regarding the formulation of strategies.

Sheingold (1973) investigated the information storage capacity of four different age groups (mean ages 5 years, 9 months; 8 years, 6 months; 11 years, 9 months; and 21 years, 9 months). Subjects were instructed to view tachistoscopically presented arrays which consisted of seven geometric figures and one blank space. Upon presentation of the figures (using nine different time intervals) the subject was to verbally identify that figure. Two different orders of presentation were used. One half of the subjects were assigned to one order of presentation and the other half to another. This study revealed that five year olds, as well as adults, were capable of encoding a large amount of information. However, the five year old group had difficulty with the condition in which there was little processing time provided. Sheingold (1973) concluded that these differences appeared to be in the processing sequence. It was reasoned that large differences in levels of performance between the five year old group and the three older age groups may have been due to the ability of the older subjects to use scanning and encoding strategies.

Rothstein (1977) has proposed that performance differences between children and adults could be due to differences in the ability to utilize feedback strategies. She suggested that the use of feedback should be a criterion for assessing any interaction between successful or unsuccessful performance and the method by which the motor plan was executed. Rothstein concluded that children lack the past experience necessary for efficient information processing and refined performance.

In his discussion of differences in skilled behavior of children and adults, Wade (1976) noted that as a person becomes a more efficient performer, more information may be processed in a given amount of time. While the adult has learned how to organize and process information presented to him/her, the child must attend to the entire stimulus array since he/she has not learned to selectively attend to specific stimuli. Wade suggested that this difference in processing is demonstrated by the child's lack of: (a) speed of response, (b) anticipation, and (c) timing behavior. Wade also has contended that the child's failure to efficiently reduce the discrepancy between the actual performance and what is intended, is further evidence of poor processing. Some theorists have suggested that the child must pass through distinct stages of maturation and learning (Gesell, 1946; Kay, 1969), becoming more proficient in the execution of skills as he/she approaches adulthood (Cratty, 1979; Kay, 1969).

Williams (1973) has proposed that the concept of perceptual-motor development is one which reflects changes in the child's ability to process increasingly complex information for use in executing a motor skill. Williams (1974) explained differences in performance levels of adults and children in regard to: (a) encoding of information, (b) attention, (c) rehearsal strategies in a wholistic sense, and (d) intersensory integration which enables the person to match and evaluate input before deciding which motor response to use. In further explanation of adult-child performance differences, Williams referred to the concept (Eccles, 1966; Jacobson, 1969) that experience facilitates the development of an increased capacity for encoding new information by the addition of a variety of functionally different frames of reference or holograms. Williams (1974) has suggested that acquisition of these frames of reference is directly related to experience the child has had as he/she has developed. As maturation of the nervous system occurs, the child is presumably able to begin to develop multisensory frames of reference which enable him/her to integrate sensory information. Williams (1974) has further proposed that the capacity for intersensory integration may be a key factor in information processing differences which are age-related.

Retarded children and adults. Brown, Campione, and Murphy (1977) have found that retarded subjects perform more poorly on memory tests than normal subjects. Brown et al. (1977) have contended that instead of having a storage system which is defective, retarded persons do not use strategies of learning or retention, as evidenced by highly variable performance. In their study learned memory strategies appeared not to be used when a new situation demanded recall (Brown et al., 1977). Reid (1980) observed that strategies are a useful tool in reducing error during performance by retarded subjects. He reported evidence which supported the findings of Brown et al. (1977) in that retarded subjects were unable to generalize the strategy to a new situation.

Campione and Brown (1977) have pointed out that there has been no evidence presented which would indicate that a retarded child can generalize a specific strategy to a new situation. They have based their work on the assumption that the components of strategies are either present within the individual or not. Therefore, they argue that the lack of successful performance represents an inability to retrieve and sequentially order informational components in order to meet the demands of the task. Campione and Brown (1978) have suggested that deficiencies in information processing by retarded persons are reflective of an inability to use strategy components as a means to accomplish an end.

## Reaction Time

Interest in the speed with which decisions can be made has generated a great deal of research. In most experiments of this nature a reaction time paradigm is utilized. Indeed, psychologists have long used reaction time as a measure of the efficiency of an individual's decision making process (Hoover, Wade, & Newell, 1981; Marteniuk, 1976; Pachella, 1974). Schmidt (1975) has defined reaction time as "the time from an unexpected signal until the beginning of overt movement" (p. 30). Others (Marteniuk, 1976; Pachella, 1974) have defined reaction time as an interval of time which is measured from the onset of the presentation of an event or stimulus to the initiation of the response.

Information processing theory offers a useful framework for the investigation of cognitive functions which involve selection, transformation, and retention of information (Nettlebeck & Brewer, 1981). During the interval of time between stimulus presentation and response initiation at least four events are assumed to occur: (a) activation of a sensory receptor, (b) transmission of a neural signal from the receptor to the brain, (c) processing of the stimulus by the brain, and (d) issuance of motor commands from the brain to a specific muscle or muscle group. Psychologists have traditionally viewed the decision process as a limiting factor in the individual's ability to process information rapidly (Marteniuk, 1976). Thus, the reaction time paradigm allows investigators to suggest limits which are imposed upon the person as he/she chooses a course of action (Marteniuk, 1976).

Reaction time research has focused on the development of the reactive process from birth to adulthood. Research studies have demonstrated that reaction time is an inverse function of age (Eckert & Eichorn, 1977; Fulton & Hubbard, 1975) up to about the age of 18 (Henry, 1961; Thomas et al., 1981). Connolly (1970) has suggested that decision making is one of the processing limitations which hinders the child in sequentially ordering components of a motor skill which would produce fluid performance.

Research studies in which both retarded and nonretarded subjects were used have focused on a number of aspects of motor skill. It has been reported that: (a) performance levels of retarded individuals are lower than performance levels of nonretarded individuals, and (b) patterns of performance differences across gender and age follow a similar pattern for retarded persons and for nonretarded persons (Francis & Rarick, 1959; Rarick, Dobbins, & Broadhead, 1976; Sloan, 1951). Investigators in the field of mental retardation have employed reaction time as a measure of an individual's ability to adapt to his/her environment and respond appropriately. In several studies speed of response has been utilized as an index of accomplishment (Baumeister & Kellas, 1968c). Baumeister and Kellas (1968c) and Nettlebeck (1980) also contended that it is reasonable to suggest possible causes of cognitive impairments from reaction time research.

Retarded children and adults. Reaction time studies investigating the performance of retarded subjects have generally involved: (a) comparisons with the performance of nonretarded subjects and (b) the examination of factors which affect reaction time performance (Nettlebeck & Brewer, 1981). There has been general agreement among researchers that when the two groups are matched according to chronological age, retarded subjects perform with a slower and more variable reaction time than do their nonretarded counterparts (Baumeister, 1968; Baumeister & Kellas, 1968a; 1968b; 1968c; Berkson & Baumeister, 1967; Gosling & Jenness, 1974; Jones & Benton, 1968; Kellas, 1969; Krupski, 1977; Terrell & Ellis, 1964).

Baumeister and Kellas (1968a) examined the performance patterns of nonretarded and retarded subjects over multiple trials on a serial response time task. They found that the pattern of response for the two groups was significantly different. Specifically, the distribution of reaction time scores of retarded subjects was less skewed (positively) but was more variable than that of the nonretarded subjects. The reaction time performance over trial blocks was significantly faster for the nonretarded subjects than for retarded subjects.

The investigation of differences in the level of reaction time performance between nonretarded children and their adult counterparts has revealed patterns similar to those found in comparisons between retarded and nonretarded subjects. In other words, reaction time scores decrease as chronological age increases (Bankhead & MacKay, 1982; Ellis & Sloan, 1957) in the same way it does as mental age increases (Ellis & Sloan, 1957). Bankhead and MacKay (1982) found that younger subjects performed with greater intra-individual variability than did older subjects. Similarly, nonretarded subjects have been found to perform on reaction time tasks with less intra-individual variability than their retarded counterparts (Bankhead & MacKay, 1982; Baumeister & Kellas, 1968b; Berkson & Baumeister, 1967; Gosling & Jenness, 1974; Kellas, 1969; Krupski, 1977).

Factors which affect reaction time have also been investigated by those who are interested in mental retardation research. Increasing the length of illumination of the warning signal (Baumeister & Kellas, 1968b; Kellas, 1969) and adding distracting stimuli during the preparatory interval (Baumeister & Kellas, 1967; Gosling & Jenness, 1974; Terrell & Ellis, 1964) have both been found to result in longer reaction time scores for retarded subjects. Baumeister and Wilcox (1969) have reported that when the preparatory interval is filled with secondary stimuli, reaction time to the primary stimulus is longer than it is when the preparatory interval is unfilled. Several studies have reported decreases in the reaction time of retarded subjects as stimulus intensity increased (Baumeister, Urquhart, Beedle, & Smith, 1964; Kellas, 1969).

Newell, Wade, and Kelly (1979) varied the complexity of a reaction time task in which the response was made more complex by (a) moving the target further away from the start button,

(b) manipulating the size of the target, and (c) varying foreperiod length. They reported that with increases in the complexity of the task, retarded subjects failed to demonstrate temporal anticipation (i.e., the ability to predict when a stimulus will arrive at a given target). However, when a simple reaction time task was used, retarded groups evidenced temporal anticipation during the block of trials in which foreperiod intervals were held constant. Newell et al. (1979) concluded that the temporal anticipation ability of retarded subjects may be a direct function of the type of response required on certain tasks. This concurred with the findings of Terrell and Ellis (1964) who reported that with a simple task, retarded subjects demonstrated temporal anticipation.

Nonretarded children and adults. There have been numerous investigations in which nonretarded subjects within a wide age range have participated. Investigations of comparable reaction time scores between adults and children have indicated that children perform with a slower reaction time than do adults (Bankhead & MacKay, 1982; Eckert & Eichorn, 1977; Fulton & Hubbard, 1975; Goodenough, 1935; Henry, 1961; Jones, 1937; Philip, 1934; Thomas et al., 1981). Eckert & Eichorn (1977) reported that a decrease in reaction time scores continues until the age of 14 years, then remains fairly stable throughout the age of 16 years (which was the upper age limit investigated in their study). Henry (1961) reported that subjects who were younger than 18 years had reaction times which were slower than those who were older than 18 years. Eckert and Eichorn (1977) reported that intra-individual variability declined only slightly and with some irregularity with increasing age. However, since there was no consistent pattern of decreasing variability with increases in age, they suggested that simple reaction time is primarily a function of the maturational level of the nervous system, and does not improve substantially with practice. In support of Eckert and Eichorn's (1977) conclusions, Bankhead and MacKay (1982) found that the oldest group in their study had the fastest reaction times and the lowest intrasubject variability. In a much earlier study, Goodenough (1935) reported that reaction time scores became more stable and less variable with increasing age.

A number of factors which might affect reaction time have been investigated. Among those which have been found to contribute to lengthened reaction time are: (a) increases in the length of the warning interval (Baumeister & Kellas, 1967), (b) addition of a secondary stimulus in the preparatory interval (Baumeister & Kellas, 1967; Baumeister & Wilcox, 1969; Gosling & Jenness, 1974); and (c) increases in stimulus intensity (Kellas, 1969). In the case of the latter factor, variability of reaction time scores has also been found to increase as stimulus intensity decreased. An exception is the work of Baumeister et al. (1964) in which no significant changes in reaction time for nonretarded subjects were found when stimulus intensity was manipulated.

## Coincidence Anticipation

Many activities in which a person participates require some degree of timing. Tyldesley and Whiting (1975) have suggested that timing is "an observable product of man's attempt to adjust his behavior to the requirements of the external environment" (p. 172). They further argue that timing ability is needed to make continual adaptation in one's environment.

With respect to prediction and anticipation, Poulton (1957) suggested that pursuit tracking involved two aspects which were common to several motor skills: (a) acquisition of a moving target and (b) recognition of the relation of position and time of a stimulus event. He suggested the existence of at least three types of anticipatory behavior. One of these, receptor anticipation, is relevant to this study. According to Poulton (1957) a receptor anticipation task has two necessary components: (a) a display of the future path or track of the target and (b) the sequential operation of a receptor mechanism and a response mechanism. Poulton (1957) contended that receptor anticipation tasks demanded more accurate timing judgment than most motor tasks.

One component of motor skills of which timing is an integral part has been identified by Belisle (1963) and is termed "coincidence anticipation." Coincidence anticipation is identified as an ability to: (a) anticipate the time a stimulus will arrive and (b) make a response coincident with that moment of arrival (Schmidt, 1968). Stadulis (1972) has suggested that this ability involves two behavioral components: (a) making the response coincident with the arrival of the stimulus at the designated point and (b) anticipating the point in time at which the response must be initiated in order to intercept the stimulus and avoid a late response due to reaction time.

Wade (1976) has observed that children's motor performance lacks the anticipatory responses of the adult performer. Weiner (1962) reported that the subject's efficiency of movement is dependent on the ability to successfully predict or anticipate the future state of a system. Support for this notion was found by Kay (1969) who investigated coincidence anticipation behavior (catching a ball) in children of three different age groups. The oldest group (15 years) exhibited an ability to rapidly anticipate the arrival of the stimulus. The younger age groups (2 and 5 years) did not demonstrate that they were able to anticipate the moment of arrival of the stimulus.

Until recently, there has been relatively little research which focused on coincidence anticipation and the timing behavior associated with it. Most timing research has involved investigation of reaction time, ignoring the important anticipatory aspect of motor behavior (Schmidt, 1968). Recently, however, there has been increased interest in the area of anticipatory timing behavior. Prior to the 1970's, most of the research has been descriptive in nature, providing initial information on coincidence anticipation behavior patterns.

Methodological considerations. Coincidence anticipation studies have commonly used three different performance error measures as dependent variables. Performance error has been defined as the difference between the performance score and the target score (Schutz & Roy, 1973). Constant error (CE) or algebraic error, has been used to describe the bias of the response and the average magnitude (direction and distance) of the response. In a coincidence anticipation setting a negative CE score would indicate an early response, and a positive CE score a late response. Variable error (i.e., intra-variance) (VE) typically has been used to describe the extent to which responses are repeated. It is the standard deviation of a subject's CE around his/her mean CE for a block of trials. Absolute error (AE) is the absolute deviation (without respect to the algebraic sign) of a subject's response from the moment or location of perfect coincidence (Schmidt, 1975; Schutz & Roy, 1973).

Coincidence anticipation studies in which these performance error measures have been utilized have not reported altogether consistent results. There are several methodological differences which might have produced these inconsistencies, i.e., (a) use of apparent or real motion tasks, (b) response complexity, and (c) subject age/developmental level.

In some studies the visual stimulus has consisted of apparent motion (Bard, Fleury, Carriere, & Bellec, 1981; Dorfman, 1977; Haywood, 1977; 1980; Haywood, Greenwald, & Lewis, 1981; Shea, Krampitz, Tolson, Ashby, Howard, & Husak, 1981; Thomas et al., 1981; Wrisberg, Martin, & Wren, 1983; Wrisberg & Mead, 1981), while in others "real" motion was used (Belisle, 1963; Dunham, 1977; Grose, 1967; McGown, Dobbins, & Rarick, 1973; Wade, 1980; Weiner, 1962). The concern here is task or ecological validity. It has not yet been determined whether these two types of tasks test the same characteristics of coincidence anticipation behavior. Reports of cross validation of novel coincidence anticipation tasks have not appeared in the literature.

Response complexity is another methodological concern. Again, there have been a variety of responses required in coincidence anticipation studies. Responses have ranged in complexity across experiments and have included movements like: (a) a finger press (Bard et al., 1981; Grose, 1967; Haywood, 1977; 1980; McGown et al., 1973; Thomas et al., 1981; Wrisberg et al., 1983), (b) a finger release (Belisle, 1963), (c) the movement of a linear slide (Dorfman, 1977), (d) the projection of an object (Wade, 1980), a foot lift (Dunham, 1977), and (e) a ballistic arm movement (Wrisberg & Mead, 1981).

Another methodological factor which merits consideration is that of age categorization. Different studies have used different age ranges to define "younger" and "older" children. The lower limit of the "young" age range has varied from 5 years (Haywood, 1977) to 8 years, 8 months (Haywood, 1980). The upper age limit has varied from 7 years (Dorfman, 1977) to 8 years, 8 months (Haywood, 1980). If one considers motor ability, developmental level, or cognitive ability, the child who is 5 years old would certainly be expected to differ from one who is almost 9 years old (Cratty, 1979; Gesell, 1946; Kay, 1969).

Recently, it has been reported (Shea et al., 1981) that of the two variables, stimulus velocity and stimulus duration, stimulus duration may be the more influential factor influencing coincidence anticipation performance. Yet, this variable has been investigated in only a few studies (Shea et al., 1981; Wade, 1980).

Alderson and Whiting (1974) have reported that prediction distance and stimulus velocity contribute to the time in which the subject is able to make predictions about a given stimulus; therefore, prediction time is assumed to influence the performance of the subject. Bard et al. (1981) have also reported that differences in stimulus velocity and/or task complexity have the potential to influence the accuracy of coincidence anticipation performance. Thus, it is clear that the interpretation of results from coincidence anticipation must be tempered by consideration of the way a variety of factors (e.g., age of subject, task complexity, stimulus velocity, stimulus duration) have been operationally defined/manipulated.

Finally, of the error measures used, VE and AE seem to furnish more consistent results across studies than does CE. This is primarily due to the fact that the mean CE of a group of individuals represents a combination of negative and positive scores which often cancel each other as a function of within group variability. Very often the group mean CE does not accurately reflect the "typical" response bias of the group.

Nonretarded children and adults. In developmental coincident timing studies, subjects have usually been classified by age into one of five different categories: (a) young children (5 to 9 years), (b) older children (10 to 12 years), (c) adolescents (13 to 17 years), (d) young adults and adults (18 to 50 years), and (e) older adults

(60 to 75 years). There appears to be a consistent line of evidence supporting the notion that coincidence anticipation performance improves with age (Bard et al., 1981; Dorfman, 1977; Dunham, 1977; Haywood, 1977; 1980; Thomas et al., 1981) up to 32 years of age (Haywood, 1980). It has been shown that the coincident timing performance of young children (5 to 9 years) exhibits less consistency and accuracy, as well as more response bias than that of older children and adults (Bard et al., 1981; Dorfman, 1977; Dunham, 1977; Haywood, 1977; Haywood et al., 1981; Thomas et al., 1981; Wade, 1980). The available research also seems to indicate that there is relatively no difference between the coincidence anticipation performance of young adolescents, young adults, and older adults (Dorfman, 1977; Haywood, 1977; Thomas et al., 1981; Wade, 1980).

In some studies, it has been shown that young children have demonstrated a negative bias (early response) to slow (44.7-134 cm/sec) stimulus speeds (Haywood, 1977; Haywood et al., 1981; Wade 1980; Wrisberg & Mead, 1981). However, in other studies, children (aged 5 to 9 years) have responded with a positive bias (late response) to slow speeds (Dorfman, 1977; Dunham, 1977; Haywood, 1980). Young children (5 to 7 years) have generally been found to respond late to fast (313-581 cm/sec) speeds (Dunham, 1977; Haywood, 1977; Thomas et al., 1981; Wrisberg & Mead, 1981), although the opposite effect (i.e., early responses to fast speeds) has been reported in one study (Wade, 1980). Interestingly, young children have been reported to be more precise in their responses to fast stimulus speeds than to slow speeds (Bard et al., 1981; Haywood, 1977; Wade, 1980; Wrisberg & Mead, 1981).

Research has revealed three relatively consistent trends in the coincidence anticipation performance of young children. First, the performance of young children appears to be less consistent with slower speed stimuli than with faster speed stimuli, with highest variability evidenced at extreme (slow or fast) speeds (Haywood, 1980; Wade, 1980). Second, young children require a substantial amount of practice in order to reduce response variability (Bard et al., 1981; Dorfman, 1977). Third, as stimulus velocity decreases, the young child's AE score increases (Dunham, 1977; Haywood, 1980; Wrisberg & Mead, 1981).

Older children (10 to 12 years) have occasionally been found to respond with a negative bias to slow speed stimuli (Haywood, 1977; Wade, 1980), although in some studies a positive bias to slow speed stimuli has been reported (Dorfman, 1977; Dunham, 1977; Haywood, 1980). Fast speeds have elicited a negative bias (Haywood, 1980; Haywood et al., 1981), positive bias (Dunham, 1977), or no bias (Haywood, 1977) in the performance of older children. Bard et al. (1981), Haywood (1977; 1980), Haywood et al. (1981) and Wade (1980) have reported that responses of older children and adolescents are more precise at fast speeds than at slow speeds.

Studies with teenagers (13 to 18 years) and young adults (19 to 35 years) have reported similarly inconsistent performance trends, particularly with respect to CE. For example, response bias has been reported to be positive (Dorfman, 1977; Haywood, 1980), negative

(Haywood, 1977), or nonexistent (Wade, 1980) with slow speed stimuli. While generally studies have revealed a positive response bias for fast speed stimuli (Haywood, 1977; 1980; Wade, 1980) one reported little or no bias for slow speeds or fast speeds (Wrisberg et al., 1983). In an investigation of coincidence anticipation of older adults (60 to 86 years), Haywood (1980) found a slight negative bias in one experiment and a slight positive bias in another.

Although the performance of all age groups has usually been shown to improve with practice, older subjects (11 to 14 years) typically demonstrate greater improvement (Bard et al., 1981; Dorfman, 1977) and greater response consistency than younger (6 to 9 years) subjects (Bard et al., 1981; Dorfman, 1977; Haywood et al., 1981; Thomas et al., 1981). In the Haywood (1980) study, separate experiments revealed that one group of older adult subjects (60 to 75 years) responded with less variability than did another (65 to 86 years). Haywood attributed this difference in variability to two factors: (a) subjects in the first experiment tended to be younger than those in the second experiment and (b) subjects in the first experiment participated in activity programs while the second group was sedentary.

Manipulations of stimulus velocity have been found to have a significant influence on the accuracy of coincidence anticipation responses (Alderson & Whiting, 1974; Bard et al., 1981; Dunham, 1977; Haywood, 1977; 1980; Shea et al., 1981; Wade, 1980; Wade, Newell, & Hoover, 1982; Weiner, 1962; Wrisberg, Hardy, & Beitel, 1982; Wrisberg et al., 1983; Wrisberg & Mead, 1981). Shea et al.

(1981) found that for young adults, as stimulus velocity increased, VE decreased. Typically, the accuracy (i.e., decreased AE) of responses of older children, adolescents, young adults, and older adults has been found to improve with increases in stimulus velocity (Haywood, 1980; Dunham, 1977; Ellingstad & Heimstra, 1969; Shea et al., 1981; Weiner, 1962; Wrisberg et al., 1982).

Retarded children and adults. McGown et al. (1973) used a coincidence anticipation task to examine the level of performance and the intra-individual variability of nonretarded and retarded children. These researchers found, as have others (Francis & Rarick, 1959; Rarick, Widdop, & Broadhead, 1970; Rarick et al., 1976) that both fine and gross motor performance of educable mentally retarded children was inferior to that of nonretarded children of the same chronological age. They reported that the intra-individual variability of the educable mentally retarded subject was also significantly greater than that of the nonretarded child. (For a more complete discussion of intra-individual variability in the performance of retarded populations see Baumeister, 1968). The reasons for these differences both in performance accuracy and in intra-individual variability have not been determined. Results of studies only show that the performance of the retarded subject is less consistent than that of the nonretarded subject.

Wade (1980) investigated the performance of educable mentally retarded and nonretarded children on a coincidence anticipation task in two separate investigations. In both experiments educable mentally retarded children were matched with nonretarded children by chronological age and by sex. Target velocity was manipulated in Experiment 1. No significant difference was found in the AE performance of nonretarded and retarded subjects. Wade (1980) found that the slowest target velocity created problems for all age groups and for both nonretarded and retarded subjects. This result conflicts with findings of previous research (Francis & Rarick, 1959; McGown et al., 1973). Possible interpretations for this discrepancy are discussed at the end of this section. Wade (1980) also found a significant effect of age with the performance of the youngest age group being less accurate than that of the older subjects.

In a second experiment, Wade (1980) varied the display time of the target and found that as viewing time decreased, error increased. Again, no significant differences were found in the performance of the nonretarded and retarded groups, which is contrary to the results of earlier research (McGown et al., 1973). In both experiments there were developmental differences in performance; but, no differences were found between subjects of differing intellectual capabilities. As previously mentioned, this conflicts with the results of prior research (Bruininks, 1974; Francis & Rarick, 1959; McGown et al., 1973; Rarick et al., 1976). Wade (1980) concluded that the young child may have a minimum range of speeds within which he/she is able to perform. Extreme speeds, fast or slow, may have the same effect on a child's anticipatory response. He also suggested that when stimuli are introduced which the child has not previously experienced, performance problems may result. Wade also suggested that the young child might be expected to have problems in retaining information about the velocity of the target if there is a time lag between successive presentations of stimuli.

There are several factors in the Wade (1980) study and the McGown et al. (1973) study which could account for differences in results of each. First, different tasks were used in the two studies. Wade used a task in which the subject watched an object move from right to left and made a ballistic response (i.e., rolling a donut-shaped object down a trackway) coincident with the arrival of the object at the end of the trackway. McGown et al. (1973) used a task in which the subject watched a metal arrow move from left to right and pressed a button coincident with the arrival of the arrow at a stationary target. Second, Wade (1980) and McGown et al. (1973) were not investigating the same independent variables. Wade (1980) was interested in stimulus velocity and stimulus duration. McGown et al. (1973) were concerned with the effect of intra-individual variability purported to influence motor performance of educable mentally retarded children. Finally, the retarded populations used in each study were different. Subjects in Wade's study were in the upper end of the IQ distribution for the mentally retarded population. Subjects in the McGown et al. (1973) study were substantially lower in the distribution. Differences in performance between these two samples of mentally retarded subjects might be predicted based on evidence presented by Bankhead and MacKay (1982), Howe (1959), Rarick et al. (1976); Sloan (1951). Each has reported that motor skill and mental ability are related, with diminished mental ability being associated with lower motor performance levels.

Possible Relationship Between Reaction Time and Coincidence Anticipation

Belisle (1963) has suggested that in order to make a response which is coincident with some stimulus or event, a decision to respond must be made at least one reaction time before the response is to be made. Although this suggests the possibility that subjects having rapid reaction times may have an advantage during performance on a coincidence anticipation task, correlations between reaction time and coincidence anticipation performance have typically been found to be very low or near zero for nonretarded adult subjects (Grose, 1967; Haywood, 1977; Thomas et al., 1981). Thomas et al. (1981) have contended that a developmental relationship might be expected to exist between reaction time and coincidence anticipation. They suggested that improvements with age in performance on reaction time tasks or coincidence anticipation tasks might be attributed to central or noncentral processing factors. Gallagher and Thomas (1980) discovered that older children (11 years) when compared to younger children (7 years) were able to process the same amount of information (input of stimulus, plan of response, initiation of response) within a shorter period of time. In addition, when older children were presented with increased amounts of information, they were able to process the information within the same time frame as when no additional information was presented.

Thomas et al. (1981) have contended that coincidence anticipation is an exemplary information processing task in that the subject is required to encode stimuli, create a plan/strategy (which includes decision making), and initiate the appropriate response. They further point out that reaction time is reflective of the initial stages of information processing. Given these presuppositions Thomas et al. (1981) obtained performance measures for simple visual reaction time and coincidence anticipation from five different age categories. These investigators found that both reaction time scores and coincidence anticipation scores decreased as a function of increasing age. More importantly, reaction time was reported to be significantly correlated with coincidence anticipation scores for nonretarded males who were 7, 9, and 11 years of age. The generalizability of this trend to other groups of nonretarded subjects or to groups of retarded subjects is presently unknown.

## Summary

Reaction time is often acknowledged as one aspect of timing ability (Baumeister & Kellas, 1968a; Marteniuk, 1976; Thomas et al., 1981). Researchers have reported that reaction time decreases with increasing age (Bankhead & MacKay, 1982; Eckert & Eichorn, 1977; Ellis & Sloan, 1957; Fulton & Hubbard, 1975; Goodenough, 1935; Henry, 1961; Jones, 1937; Philip, 1934; Thomas et al., 1981). Independent variables which have been found to be related to changes in reaction time include: (a) temporal variability (Baumeister & Kellas, 1968b),

(b) stimulus intensity (Kellas, 1969), and (c) task complexity (Bankhead & MacKay, 1982).

Reaction time studies comparing the performance of nonretarded and retarded individuals reveal slower reaction time for the latter group (Bankhead & MacKay, 1982; Baumeister, 1968; Baumeister & Kellas, 1968a; 1968b; Baumeister & Wilcox, 1969; Berkson & Baumeister, 1967; Ellis & Sloan, 1957; Gosling & Jenness, 1974; Kellas, 1969; Krupski, 1977; Terrell & Ellis, 1964). Retarded subjects also tend to perform with greater intra-subject variability than nonretarded subjects (Baumeister & Kellas, 1968a; 1968b; 1968c; Berkson & Baumeister, 1967; Gosling & Jenness, 1974; Kellas, 1969; Krupski, 1977). The manipulation of variables such as stimulus intensity appears to be related to the change in reaction time performance of retarded subjects more than that of nonretarded subjects (Baumeister et al., 1964).

Coincidence anticipation is considered by many to be an important component in motor performance (Belisle, 1963; Schmidt, 1968). Generally, it appears that change in coincidence anticipation performance is related to manipulations of stimulus velocity (Alderson & Whiting, 1974; Bard et al., 1981; Dunham, 1977; Ellingstad, 1967; Ellingstad & Heimstra, 1969; Haywood, 1977; 1980; Shea et al., 1981; Wade, 1980; Wade et al., 1982; Wrisberg et al., 1982; Wrisberg et al., 1983; Wrisberg & Mead, 1981) and that responses are more precise at fast speeds (312-581 cm/sec) than slow speeds (44.7-134 cm/sec) (Alderson & Whiting, 1974; Bard et al., 1981; Haywood, 1977; 1980; Wade, 1980; Wade et al., 1982; Weiner, 1962; Wrisberg et al., 1982; Wrisberg et al., 1983; Wrisberg & Mead, 1981). Furthermore, the available evidence seems to indicate that stimulus velocity affects the coincidence anticipation performance of young children, older children, adolescents, and adults in different ways (Alderson & Whiting, 1974; Dunham, 1977; Haywood, 1980; Wade, 1980; Wrisberg et al., 1982). Finally, of the error measures used, VE and AE seem to provide more consistent results across studies than does CE. Some novel timing tasks have been created; although intercorrelations of performance on these tasks have not been reported.

Studies addressing the coincidence anticipation performance of retarded children have produced conflicting results. While it has been shown that their performance is more variable and produces greater error than the performance of nonretarded individuals (McGown et al., 1973), a second study (Wade, 1980) has not reported such trends. It is possible that the differences which have been noted are due to methodological inconsistencies and not to differences in the subjects' performance levels.

It has been suggested that in most motor skills which involve a continuous movement, the proficient and skilled performer must make certain predictions concerning important stimuli. Others have implied that rapid reactions may be beneficial to accurate anticipation and timing (Poulton, 1965; Thomas et al., 1981). Research has revealed that for nonretarded populations, accurate anticipation of a stimulus will decrease the time necessary for response initiation in a discrete movement task (Adams & Creamer, 1962; Klemmer, 1956; 1957);

however, knowledge concerning the role of coincidence anticipation in a continuous movement is limited (Thomas et al., 1981).

Studies investigating the relationship between reaction time and coincidence anticipation have been conducted using nonretarded subjects (Grose, 1967; Haywood, 1977; Thomas et al., 1981). A positive relationship between the two timing abilities has been reported for young age groups (Thomas et al., 1981). As age increases this relationship becomes weaker (Grose, 1967; Haywood, 1977; Thomas et al., 1981).

Few studies have investigated the developmental characteristics of children's timing performance which could give information as to processing needs (Thomas et al., 1981). The literature contains an abundance of descriptive evidence which provides comparative information about the performance of children and adults (Kay, 1969; Reid, 1980; Wade, 1976); however, few studies have been conducted which tease out explanations for such developmental differences in performance. Those explanations indicate something about how an individual learns (Wade, 1976).

Even fewer studies of this type have been conducted with retarded subjects. In general, research involving retarded subjects has contributed to a general body of knowledge about the effect of intellectual impairment on performance (Campione & Brown, 1978), or regarding possible processes underlying timing behavior (Baumeister & Kellas, 1968c).

The different phases of an information processing model are reflected in the demands of a coincidence anticipation task (Thomas et al., 1981). It has been suggested that reaction time is reflective of part of the information process in that it primarily represents decision time (Marteniuk, 1976). For the nonretarded population, older children (Gallagher & Thomas, 1980) and adults (Haith et al., 1970) have been shown to be more efficient processors than young children (Gallagher & Thomas, 1980; Haith et al., 1970); therefore, as mental age increases so do the processing capabilities. It is possible that young children with lower mental ages view the two tasks in a different way than do older individuals with higher mental ability. Moreover, it might be predicted that retarded individuals and nonretarded children (possessing comparable mental ages) demonstrate similar patterns of relationship between reaction time and coincidence anticipation performance. In order to investigate this possibility as well as to determine age-related differences in the perceptual-motor performance and the information processing capabilities of retarded and nonretarded individuals, the present study was conducted.

# CHAPTER III

# PROCEDURES

This chapter provides information which will identify and describe the (a) subjects, (b) apparatus, and (c) procedures used in this study. The information in the latter two categories will pertain first to the reaction time task, and then to the coincidence anticipation task.

## Subjects

Permission was obtained from superintendents and principals of school systems in Anderson, Blount, and Sevier Counties, Tennessee, to use nonretarded and retarded male students as participants in this study. Parental permission forms, accompanied by a letter explaining each task, were sent to the parents of students who met the requirements for the project (Appendix A). Before the student could participate, he had to return the permission form which had been signed by his parent or guardian.

Retarded subjects were students in three different types of schools. The majority of subjects in the younger two age categories attended a school which was designed to meet the needs of the mentally deficient. These children, for various reasons, were not able to be placed in a regular school setting. Others of these two age categories (7-8, 9-10) were students at schools which had designed special programs for the retarded child. For the most part these children remained in these classes for the school day. Another group of subjects in the 11-12 and the 13-14 year old category attended schools which had special programs designed for them for part of the day. These individuals were also mainstreamed into regular classes where it was appropriate. Four of the eight subjects in the 17-20 year old category were students at a local high school, and were mainstreamed into classes at their school. One of the subjects who was in the 17-20 year old category was a student at a resource center for the mentally deficient. This school was similar to the school in which the 7-8 and 9-10 year olds were enrolled.

The subjects were classified by one of the following chronological age categories of growth and development: (a) 7 years, 0 months through 8 years, 10 months, (b) 9 years, 0 months through 10 years, 10 months, (c) 11 years, 0 months through 12 years, 10 months, (d) 13 years, 0 months through 14 years, 10 months, and (e) 17 years, 0 months through 20 years, 10 months. Each age category consisted of eight retarded and eight non-retarded subjects. Although prior investigations (Thomas et al., 1981; Wade, 1980) have not used these specific age limits, others (Cratty, 1979; Gesell, 1946) have contended that these age limits best represent the typical stages of growth and development.

Apparatus

Reaction time apparatus. A visual stimulus unit (Model 63030, Lafayette Instrument Company) was used to present stimuli on reaction time trials. Reaction time was measured by a stop clock (Model 63017, Lafayette Instrument Company) which was interfaced with the visual stimulus apparatus. Also connected to the clock were an initiation key and a response key; thus, the apparatus consisted of four components: (a) the stimulus apparatus, (b) the stop clock, (c) the initiation key, and (d) the response key. The stimulus apparatus consisted of a box (11 cm in length, 10 cm in width) on which were mounted two small bulbs. A white "warning" bulb (.6 cm diameter) was positioned on the front of the box 2 cm above a red "stimulus" bulb (1.3 cm diameter). The stop clock was mounted on a control unit which was 20.6 cm in height, 35.5 cm in width, and 25.3 cm in depth. The initiation key and the response key (2.8 cm diameter) were similar in design to a telegraph key, and were mounted on a board 19.8 cm in length, 12.4 cm in width, and 1.2 cm in height. Also mounted on the control units were switches which allowed: (a) selection of foreperiod duration, (b) selection of the stimulus mode (visual or auditory), (c) stimulus presentation, and (d) resetting of the clock.

A trial was initiated when the subject depressed and held down the initiation key. The experimenter then pushed the "initiate" button which preceded the following sequence of events: (a) illumination of the white warning light, (b) offset of the warning light, (c) variable foreperiod, (d) illumination of the red stimulus light and activation of the clock; (c) release of the initiation key by the subject (which stopped the clock), and (f) depression of the response key (which extinguished the red stimulus light).

Coincidence anticipation apparatus. A Bassin Anticipation Timer (Model 50-575, Lafayette Instruments Company) was used to measure the timing accuracy of each subject. The apparatus consisted primarily of three components: (a) a trackway (Model 50-575-R, Lafayette Instruments Company), (b) a control unit, and (c) a response key. The trackway consisted of three sections which were connected end to end. Each section was 76 cm in length, 8.5 cm in width, and 6.6 cm in height with 16 red bulbs (.6 cm diameter) spaced 4.5 cm apart (center to center). At the end of the last section adjacent to the bulb on the trackway nearest the subject was a piece of white tape, the length of which was equal to the width of the trackway. This tape served to accentuate the location of the lamp on the runway closest to the subject (i.e., the target lamp). At the end of the trackway furthest from the subject was a white warning lamp, the illumination of which served as a signal to alert the subject that the sequence of apparent motion was about to begin.

The control unit (Model 50575, Lafayette Instruments Company) was 25.7 cm in width, 17.4 cm in depth, and 12.8 cm in height. Mounted on the front of the control unit were switches which allowed: (a) initiation of the light sequence of apparent motion and (b) resetting of the timer. A digital display presented the subject's error (in msec) on each trial. An error represented the difference between the moment of arrival of the stimulus at the target point and the moment of key depression by the subject. Mounted on the control unit to the left of the digital display were two bulbs which signaled to the experimenter whether the response was "early" (i.e., key depression occurring before the moment of illumination of the target lamp) or "late" (i.e., key depression occurring after the moment of target lamp illumination). As indicated earlier, the lamp located nearest the subject functioned as the target lamp. A trial began when the experimenter pushed the initiate button which preceded the following sequence of events: (a) illumination of the yellow warning light and (b) sequential illumination and offset of the red lights which were arranged in a linear sequence on the trackway. Key depression by the subject caused the clock to stop. None of the bulbs, including the last bulb in the series, remained illuminated following key depression (i.e., the subject was not able to "stop" the illumination sequence at any specific point on the trackway).

Procedures

Data collection for this study was begun in March 1983 and was completed in June 1983. Testing was conducted in 13 schools which were located in school systems in Anderson, Blount, and Sevier Counties, Tennessee.

Pilot testing. Previous research (Haywood & Teeple, 1976) has shown that in a reaction time task involving nonretarded adults, eight trials were needed to achieve baseline performance. A number of reaction time studies with children (Berkson & Baumeister, 1967; Ellis & Sloan, 1957; Goodenough, 1935; Kellas, 1969; Krupski, 1977) have used different numbers of familiarization trials, ranging from 12 to 50.

The number of familiarization trials needed for retarded children had not been determined prior to this study. In order to determine an appropriate number of trials to use with the Bassin Timer, a pilot study was conducted which involved retarded subjects (IQ range of 50 to 69) whose ages ranged from 9 years, 0 months to 11 years, 11 months. The level of performance of most of these subjects peaked by Trial 15. For each age group, a slight decline in performance was observed beginning with the seventeenth and eighteenth trials, many of the subjects appeared to be distracted, disinterested, or fatigued. Thus, for the present study, 20 trials were administered, 6 trials to familiarize and assure comprehension of the task, 10 trials for a performance measure, and 4 final trials. The number of initial trials used in the present study (i.e., six trials) is consistent with that used by Thomas et al. (1981) who gave eight preliminary trials to eliminate learning effects.

## Reaction Time Task

General procedures. As the subject entered the room, he was instructed to sit in a chair of appropriate size for the individual, facing the apparatus (Appendix D). In order to determine the subject's preferred hand he was asked, "Which hand do you write/color with?" If there was hesitation or question on the part of the subject, the subject's teacher was consulted. After determining the subject's preferred hand, the experimenter positioned the subject so that the initiation key was directly in front of him.

The response key, identical in design to the initiation key, was positioned 10.16 cm to the right (or left dependent upon the subject's preferred hand) of the initiation key (Appendix D). Movement from the initiation key to the response key provided the subject with visual feedback that he had accomplished the goal of the task (i.e., depression of the response key extinguished the red stimulus lamp). This event was instrumental in sustaining the attention of both nonretarded and retarded subjects. The stimulus box was positioned 10.16 cm above the response key, allowing the subject to see both the stimulus light and the response key as he moved his hand from center to right or center to left. If the subject was right handed, he moved his hand to the right to the response key. If he was left handed, he moved his hand to the left.

In order to familiarize the subject with the apparatus and the task, the following instructions were given to the two younger age groups of nonretarded subjects and to the first four age groups of retarded subjects. Modification of these instructions was made according to the needs of the subjects in the older age groups or for any subject as was considered necessary. The subject was told that when he heard the word, "Ready," he was to depress the initiation key with the index and middle fingers of his preferred hand, without resting his hand on the table. He was instructed to direct his attention to the stimulus box. The subject was told that if he kept the key in this position, a white bulb would illuminate and then extinguish; and that a red light would then illuminate. He was informed that the lighting of the red light meant that he was to move his hand from the initiation key to the response key, depressing the latter in as fast a time as possible. During the instruction phase of the testing, subjects were given the opportunity to view the operation of the apparatus and to perform the task with verbal assistance from the experimenter. Five initial trials were then administered. After the subject had completed these trials, he was asked the following questions: (a) "What are you supposed to do when I say, 'Ready?'" (b) "Where are you supposed to watch after I say, 'Ready?'" (c) "What are you supposed to do when the red light comes on?" If the subject did not answer these questions correctly, further instruction and practice opportunities were allowed.

In an earlier study, Holden (1966) used as many trials as were necessary for understanding. For the purpose of the present study, comprehension of the task was determined by correct response to instructions in the initial trials and by correct answers to the questions which followed the initial five trials. If these two criteria were not met, further instruction was given to the subject. After these two criteria were met, the sixth trial was administered for the purpose of redirecting the subject's attention to the task. The remainder of the trials were then administered to the subject. No knowledge of results was given to the subject regarding his reaction time performance.

Coincidence Anticipation Task

The subject entered the room and was instructed to sit in a chair which faced a desk on which the response key was located (Appendix D). The size of the chair and desk varied according to the size of the individual. Each subject was positioned with the midline of his body perpendicular to the Bassin trackway, the near end of which was 204.47 cm from the response key. The response key which was placed on top of the desk was 5.08 cm from the edge of the desk closest to the subject. The trackway was positioned in the center of a table top which was 53.34 cm from the floor (Appendix D).

In the pilot study which was discussed earlier, subjects were tested at five different speeds: (a) 44.7 cm/sec (1 mph), (b) 134 cm/sec (3 mph), (c) 224 cm/sec (5 mph), (d) 313 cm/sec (7 mph), and (e) 403 cm/sec (9 mph). One of the purposes of the present study was to determine the subject's ability to anticipate the arrival of a moving stimulus at a predetermined target. Results from the pilot study revealed that subjects performed with the least amount of error at 134 cm/sec; therefore, this velocity was utilized in the present study.

Instructions were given to the subject to familiarize him with the task and the apparatus. Modification of the instructions was made as was necessary to assure comprehension on the part of the subject. The subject was instructed to direct his attention to the top of the trackway, observe the illumination sequence, and then verbally report to the experimenter what had happened. Each subject was asked the following questions: (a) "What do you see?" (b) "Is it moving or standing still?" (c) "What color is the moving light?" None of the subjects were unable to answer these questions. The experimenter then instructed the subject to place the index and middle fingers of the preferred hand on the key located in front of the subject. The subject was allowed to rest the heel of his hand on the table. The subject was told that when he heard the word, "Ready," he was to focus his attention on the white warning light at the far end of the trackway. He was then instructed to "watch the light as it moves down the trackway; and, at the <u>same time</u> that the light reaches the last lamp on the trackway, press down the key."

The subject was given five initial trials, after which the following questions were asked in order to give evidence of the subject's comprehension of the task:

1. "Where are you supposed to look when I say, 'Ready?'"
2. "What are you supposed to do at the <u>same time</u> the light

gets right here?" (Experimenter pointing to the target lamp).

For some of the subjects, the following question was also asked:

3. "Are you supposed to push the button when the light is here?" (Experimenter pointing to the middle trackway section). "Here?" (Experimenter pointing to the first trackway section). "Here?" (Experimenter pointing to the last trackway section). "Show me where the light should be at the same time you push the button."

In order to redirect the subject's attention to the task a sixth trial was administered followed by presentation of the remaining trials. No knowledge of results was given to the subject regarding his coincidence anticipation performance.

In an attempt to prevent possible order effects and to further insure internal validity, a counterbalanced procedure was used with each subject assigned to one of the two following orders of task presentation: (a) reaction time then coincidence anticipation trials, or (b) coincidence anticipation then reaction time trials. Each subject was tested on two consecutive days. Subjects were tested individually with each session taking approximately 15 to 20 minutes.

# CHAPTER IV

# RESULTS

In this chapter (a) the methods used in data analysis and (b) the results of the data analysis will be presented. Each of the five hypotheses is restated and accompanied by the results of the analysis for that hypothesis.

## Data Analyses

Assessment of reaction time and coincidence anticipation performance was conducted using the central 10 scores (i.e., trials 7-16) of the 20 trials for each subject for each task (see Chapter III for rationale). For reaction time performance, the median score of the 10 trials for each subject was analyzed as the dependent measure. Constant error (CE) and variable error (VE) have commonly been used as error measures for coincidence anticipation performance (Schmidt, 1975). According to Schutz and Roy (1973), CE and VE scores allow the clearest and least repetitive information about the accuracy of a person's performance. These researchers have mathematically demonstrated that absolute error (AE) is a combination of CE and VE. In light of this fact, AE was not used in the data analysis for the present study. The CE score was obtained by determining the median of the central 10 scores (i.e., trials 7-16). The VE score was calculated as the standard deviation of a subject's CE scores around his median CE for the 10 trials. Differences were considered significant at the alpha level of .05.

The F (folded) statistic (Steele & Torrie, 1960) was computed in the TTEST procedure of SAS 79 (Ray, 1982) to test the assumption that the variances were equal. Because variances were found to be significantly ($p < .05$) different for all dependent measures, a subsequent log transformation was performed on the data. However, the TTEST procedure again indicated unequal variances; therefore, a Kruskal-Wallis one-way analysis of variance was conducted on each of the dependent measures for each age and IQ group (Siegel, 1956). Subsequent post hoc analysis using the Mann-Whitney-Wilcoxen procedure was performed, where appropriate, to locate the source of significant differences. The Spearman rank order correlational technique (Siegel, 1956) was used to determine whether significant correlations existed between the dependent measures of median reaction time and median absolute CE (the absolute value of each subject's median CE). The RT and CE measures for each trial, task and subject are presented in Appendix C

Hypothesis 1

There will be no significant difference in the median reaction time scores among age categories within either group: (a) retarded or (b) nonretarded.

Retarded subjects. Median reaction time scores for each age category and the Kruskal-Wallis test summary table for median reaction times are presented in Table I. Summary statistics for the Mann-Whitney-Wilcoxen procedure are presented in Table II. Inspection of these tables reveals that median reaction time decreased as a function

TABLE I

Summary Statistics for the Kruskal-Wallis Analysis Reaction Time: Retarded Subjects

| Age Category | N | Sum of Ranks | Expected Under Ho | Kruskal-Wallis Analysis | Group Median Score |
|---|---|---|---|---|---|
| 7-8 | 8 | 252.00 | 164.00 | | .5925 |
| 9-10 | 8 | 221.00 | 164.00 | | .4965 |
| 11-12 | 8 | 188.00 | 164.00 | $X^2(4) = 24.74$, $p < .05$ | .4755 |
| 13-14 | 8 | 104.00 | 164.00 | | .358 |
| 17-20 | 8 | 55.00 | 164.00 | | .318 |

TABLE II

Summary Statistics for the Mann-Whitney-Wilcoxen Analysis
Reaction Time: Retarded Subjects

| Comparison | N | 7-8 | 9-10 | 11-12 | 13-14 | 17-20 | S/NS |
|---|---|---|---|---|---|---|---|
| 7-8 vs 9-10 | 8 | 80 | 56 | | | | NS |
| 7-8 vs 11-12 | 8 | 84 | | 52 | | | NS |
| 7-8 vs 13-14 | 8 | 97 | | | 39 | | S |
| 7-8 vs 17-20 | 8 | 100 | | | | 36 | S |
| 9-10 vs 11-12 | 8 | | 74 | 62 | | | NS |
| 9-10 vs 13-14 | 8 | | 99 | | 37 | | S |
| 9-10 vs 17-20 | 8 | | 100 | | | 36 | S |
| 11-12 vs 13-14 | 8 | | | 86 | 50 | | NS |
| 11-12 vs 17-20 | 8 | | | 95 | | 41 | S |
| 13-14 vs 17-20 | 8 | | | | 86 | 50 | NS |

of increasing age. Within each of the youngest age categories, the intersubject variability was quite large. A substantial reduction in the range of the medians was observed in the 13-14 year old group as well as in the 17-20 year old group. A Kruskal-Wallis one-way analysis of median reaction time scores revealed a significant effect of age, $\underline{X}^2(4) = 24.74$, $\underline{p} < .05$. Thus, Hypothesis 1(a) was rejected. The median reaction time scores of the 7-8 year olds, the 9-10 year olds, and the 11-12 year olds were not significantly different; but, all three groups had significantly slower reaction times than the 13-14 year olds and the 17-20 year olds. The scores of the latter two age groups were not significantly different.

Nonretarded subjects. The median reaction time scores for each age category and the Kruskal-Wallis test summary table are presented in Table III. The summary statistics for the Mann-Whitney-Wilcoxen procedures are presented in Table IV. As in the case of retarded subjects, median reaction time for the nonretarded group appeared to decrease as age increased. The range of scores within and between age categories was relatively small.

The analysis of median reaction time scores across ages for this group revealed an overall significant effect, $\underline{X}^2(4) = 23.43$, $\underline{p} < .05$; therefore, Hypothesis 1(b) was rejected. Post hoc procedures revealed that the median reaction time scores of the 7-8 year old group were significantly slower than those of each of the four older age groups. The scores of the 9-10 year olds, 11-12 year olds, and 13-14 year olds were not significantly different, but the reaction

TABLE III

Summary Statistics for the Kruskal-Wallis Analysis
Reaction Time: Nonretarded Subjects

| Age Category | N | Sum of Ranks | Expected Under Ho | Kruskal-Wallis Analysis | Group Median Score |
|---|---|---|---|---|---|
| 7-8 | 8 | 258.00 | 164.00 | | .3885 |
| 9-10 | 8 | 195.00 | 164.00 | | .3400 |
| 11-12 | 8 | 171.50 | 164.00 | $X^2(4) = 23.43$, $p < .05$ | .3010 |
| 13-14 | 8 | 134.00 | 164.00 | | .3275 |
| 17-20 | 8 | 61.00 | 164.00 | | .2850 |

TABLE IV

Summary Statistics for the Mann-Whitney-Wilcoxen Analysis
Reaction Time: Nonretarded Subjects

| Comparison | N | 7-8 | 9-10 | 11-12 | 13-14 | 17-20 | S/NS |
|---|---|---|---|---|---|---|---|
| 7-8 vs 9-10 | 8 | 90 | 46 | | | | S |
| 7-8 vs 11-12 | 8 | 84 | | 42 | | | S |
| 7-8 vs 13-14 | 8 | 100 | | | 36 | | S |
| 7-8 vs 17-20 | 8 | 100 | | | | 36 | S |
| 9-10 vs 11-12 | 8 | | 82 | 54 | | | NS |
| 9-10 vs 13-14 | 8 | | 79 | | 57 | | NS |
| 9-10 vs 17-20 | 8 | | 95 | | | 41 | S |
| 11-12 vs 13-14 | 8 | | | 53 | 83 | | NS |
| 11-12 vs 17-20 | 8 | | | 88 | | 48 | S |
| 13-14 vs 17-20 | 8 | | | | 97 | 39 | S |

times of all three of these groups were significantly slower than that of the 17-20 year old group.

Hypothesis 2

There will be no significant difference in the coincidence anticipation performance (CE and VE) among age categories within either group: (a) retarded or (b) nonretarded.

Retarded Subjects The VE scores, median CE scores and the Kruskal-Wallis test summary are presented in Table V. Summary statistics for the Mann-Whitney-Wilcoxen procedure conducted on VE scores are presented in Table VI. For CE there was no significant difference between age groups, $\underline{X}^2(4) = 4.23$, $\underline{p} > .05$

As age increased, VE generally appeared to decrease. The VE for each of the three youngest age categories was very large. However, there was a substantial decrease in VE for the 13-14 year old age group and a further reduction for the 17-20 year old category. An analysis of VE scores revealed a significant age effect, $\underline{X}^2(4) = 17.33$, $\underline{p} < .05$; therefore, Hypothesis 2(a) was rejected for VE. Mann-Whitney-Wilcoxen post hoc procedures revealed that the VE of 7-8 year olds, 9-10 year olds, and 11-12 year olds was not significantly different. The VE of the first two age categories was significantly higher than that of 13-14 year olds and the VE of the 11-12 year olds, and 17-20 year olds, was not significantly different.

TABLE V

Summary Statistics for the Kruskal-Wallis Analysis
Constant and Variable Error: Retarded Subjects

| Age Category | N | Sum of Ranks | Expected Under Ho | Kruskal-Wallis Analysis | Group Median Scores |
|---|---|---|---|---|---|
| Constant Error | | | | | |
| 7-8 | 8 | 184.00 | 164.00 | | +.1710 |
| 9-10 | 8 | 203.00 | 164.00 | $X^2(4) = 4.23$, $p > .05$ | +.1945 |
| 11-12 | 8 | 174.00 | 164.00 | | +.1230 |
| 13-14 | 8 | 119.00 | 164.00 | | +.0757 |
| 17-20 | 8 | 140.00 | 164.00 | | +.04825 |
| Variable Error | | | | | |
| 7-8 | 8 | 240.00 | 164.00 | | .2960 |
| 9-10 | 8 | 217.00 | 164.00 | | .2155 |
| 11-12 | 8 | 177.00 | 164.00 | $X^2(4) = 17.33$, $p < .05$ | .1815 |
| 13-14 | 8 | 100.50 | 164.00 | | .0695 |
| 17-20 | 8 | 85.50 | 164.00 | | .0720 |

TABLE VI

Summary Statistics for the Mann-Whitney-Wilcoxen Analysis
Variable Error: Retarded Subjects

| Comparison | N | 7-8 | 9-10 | 11-12 | 13-14 | 17-20 | S/NS |
|---|---|---|---|---|---|---|---|
| 7-8 vs 9-10 | 8 | 73 | 63 | | | | NS |
| 7-8 vs 11-12 | 8 | 78 | | 58 | | | NS |
| 7-8 vs 13-14 | 8 | 97 | | | 39 | | S |
| 7-8 vs 17-20 | 8 | 100 | | | | 36 | S |
| 9-10 vs 11-12 | 8 | | 74 | 62 | | | NS |
| 9-10 vs 13-14 | 8 | | 91 | | 45 | | S |
| 9-10 vs 17-20 | 8 | | 94 | | | 42 | S |
| 11-12 vs 13-14 | 8 | | | 81 | 55 | | NS |
| 11-12 vs 17-20 | 8 | | | 84 | | 52 | NS |
| 13-14 vs 17-20 | 8 | | | | 72.5 | 63.5 | NS |

Nonretarded subjects. The VE scores, median CE scores for each age category and test summary for the Kruskal-Wallis analysis are presented in Table VII. Summary statistics for the Mann-Whitney-Wilcoxen procedure conducted on VE scores are presented in Table VIII. For CE, there was no significant difference between age groups, $\underline{X}^2(4) = 5.30$, $\underline{p} > .05$. For CE, Hypothesis 2(b) was not rejected.

For this IQ group, the individuals in the oldest category responded most consistently; that is, as age increased, VE decreased. However, within each age category there was a wide variability of VE scores. An analysis of VE scores revealed a significant age effect, $\underline{X}^2(4) = 19.44$, $\underline{p} < .05$; therefore, Hypothesis 2(b) was rejected for VE. Post hoc Mann-Whitney-Wilcoxen procedures indicated that the VE for the 7-8 year old group was significantly higher than that of all other groups with the exception of the 9-10 year olds. Although VE scores decreased as age increased, there was no significant difference in VE between the 9-10 year olds, the 11-12 year olds, and the 13-14 year olds. However, each of those groups had VE scores which were significantly higher than that of the 17-20 age category.

## Hypothesis 3

There will be no significant difference in the median reaction time scores of retarded and nonretarded groups for any of the five age categories.

The median reaction time scores for each age category for each IQ group and test summary for the Kruskal-Wallis analysis are presented in Table IX. The summary statistics for the Mann-Whitney-

TABLE VII

Summary Statistics for the Kruskal-Wallis Analysis Constant and Variable Error: Nonretarded Subjects

| Age Category | N | Sum of Ranks | Expected Under Ho | Kruskal-Wallis Analysis | Group Median Scores |
|---|---|---|---|---|---|
| Constant Error | | | | | |
| 7-8 | 8 | 227.50 | 164.00 | | +.0740 |
| 9-10 | 8 | 160.50 | 164.00 | | +.0480 |
| 11-12 | 8 | 136.00 | 164.00 | $X^2(4) = 5.30$, $p > .05$ | +.0560 |
| 13-14 | 8 | 133.00 | 164.00 | | +.0350 |
| 17-20 | 8 | 163.00 | 164.00 | | +.0545 |
| Variable Error | | | | | |
| 7-8 | 8 | 258.00 | 164.00 | | .0735 |
| 9-10 | 8 | 195.00 | 164.00 | | .0515 |
| 11-12 | 8 | 171.50 | 164.00 | $X^2(4) = 19.44$, $p < .05$ | .0490 |
| 13-14 | 8 | 134.00 | 164.00 | | .0405 |
| 17-20 | 8 | 61.50 | 164.00 | | .0280 |

TABLE VIII

Summary Statistics for the Mann-Whitney-Wilcoxen Analysis
Variable Error: Nonretarded Subjects

| Comparison | N | 7-8 | 9-10 | 11-12 | 13-14 | 17-20 | S/NS |
|---|---|---|---|---|---|---|---|
| 7-8 vs 9-10 | 8 | 82 | 54 | | | | NS |
| 7-8 vs 11-12 | 8 | 89 | | 47 | | | S |
| 7-8 vs 13-14 | 8 | 92.5 | | | 43.5 | | S |
| 7-8 vs 17-20 | 8 | 98.5 | | | | 37.5 | S |
| 9-10 vs 11-12 | 8 | | 73 | 63 | | | NS |
| 9-10 vs 13-14 | 8 | | 82 | | 54 | | NS |
| 9-10 vs 17-20 | 8 | | 94 | | | 42 | S |
| 11-12 vs 13-14 | 8 | | | 78 | 58 | | NS |
| 11-12 vs 17-20 | 8 | | | 92 | | 44 | S |
| 13-14 vs 17-20 | 8 | | | | 90.5 | 45.5 | S |

TABLE IX

Summary Statistics for the Kruskal-Wallis Analysis
Reaction Time: Between Groups

| IQ Category | N | Sum of Ranks | Expected Under Ho | Kruskel-Wallis Analysis | Group Median Scores |
|---|---|---|---|---|---|
| Retarded | 40 | 2063.5 | 1620.00 | | .4755 |
| Nonretarded | 40 | 1176.50 | 1620.00 | $\underline{X}^2(1) = 18/21$, $\underline{p} < .05$ | .3010 |

Wilcoxen procedure are presented in Table X. The decrease in reaction time over the first three age categories followed a similar pattern for both retarded and nonretarded groups. However, the decrease in reaction time scores from the 11-12 year old to the 13-14 year old category appeared to be more substantial for the retarded group than for the nonretarded group.

The Kruskal-Wallis analysis of variance revealed a significant overall effect of groups, $\underline{X}^2(1) = 18.21$, $\underline{p} < .05$; thus, Hypothesis 3 was rejected. A Mann-Whitney-Wilcoxen procedure was utilized to determine the age categories for which a significant group difference existed. Analysis of data revealed a significant difference between the median reaction time scores of retarded and nonretarded groups for the following age categories: (a) 7-8 years, (b) 9-10 years, and (c) 11-12 years. In each case, nonretarded subjects had significantly faster reaction times than did retarded subjects. While the scores of nonretarded subjects in the 13-14 and 17-20 year old categories were faster than those of retarded subjects, the difference was not statistically significant.

<u>Hypothesis 4</u>

<u>There will be no significant difference in the coincidence anticipation performance (CE and VE) of retarded and nonretarded groups for any of the five age categories.</u>

The VE scores and median CE scores for each age category and IQ group and test summary for the Kruskal-Wallis analysis are presented in Table XI. The summary statistics for the Mann-Whitney-Wilcoxen

TABLE X

Summary Statistics for the Mann-Whitney-Wilcoxen Analysis
Reaction Time: Between Groups

| Comparison | | N | 7-8 | 9-10 | 11-12 | 13-14 | 17-20 | S/NS | Group Median Reaction Time Scores |
|---|---|---|---|---|---|---|---|---|---|
| R[a] | 7-8 | 8 | 91.00 | | | | | | .3885 |
| NR[b] | 7-8 | 8 | 45.00 | | | | | S | |
| R | 9-10 | 8 | | 100.00 | | | | | .4965 |
| NR | 9-10 | 8 | | 36.00 | | | | S | .3400 |
| R | 11-12 | 8 | | | 95.00 | | | | .4755 |
| NR | 11-12 | 8 | | | 41.00 | | | S | .3010 |
| R | 13-14 | 8 | | | | 83.50 | | | .3580 |
| NR | 13-14 | 8 | | | | 52.50 | | NS | .3275 |
| R | 17-18 | 8 | | | | | 86.00 | | .3180 |
| NR | 17-18 | 8 | | | | | 50.00 | | .2850 |

[a]R = Retarded

[b]NR = Nonretarded

TABLE XI

Summary Statistics for the Kruskal-Wallis Analysis
Constant Error and Variable Error: Between Groups

| IQ Category | N | Sum of Ranks | Expected Under Ho | Kruskal-Wallis Analysis | Group Median Score |
|---|---|---|---|---|---|
| Constant Error | | | | | |
| Retarded | 40 | 1728.00 | 1620.00 | | .1230 |
| Nonretarded | 40 | 1512.00 | 1620.00 | $\underline{X}^2(1) = 1.08$, $\underline{p} > .05$ | .0545 |
| Variable Error | | | | | |
| Retarded | 40 | 2095.50 | 1620.00 | | .1815 |
| Nonretarded | 40 | 1144.50 | 1620.00 | $\underline{X}^2(1) = 20.94$, $\underline{p} < .05$ | .0490 |

procedure for VE and CE scores are presented in Table XII. The Kruskal-Wallis analysis of variance revealed no overall groups effect for CE, $\underline{X}^2(1) = 1.08$, $\underline{p} > .05$, consequently, Hypothesis 4 was not rejected. However, the VE produced a significant groups effect, $\underline{X}^2(1) = 20.94$, $\underline{p} < .05$. Therefore, Hypothesis 4 was rejected for VE. A Mann-Whitney-Wilcoxen procedure was utilized to determine the age categories for which a significant group difference existed. For each IQ group, VE decreased as age increased. For each age category the within group variability of VE scores was lower for nonretarded subjects than for retarded subjects. Furthermore, VE appeared to decrease in larger increments with increasing age for the nonretarded group than for the retarded group. Post hoc analysis of VE scores revealed a significant difference between retarded and nonretarded subjects for the following age categories: (a) 7-8 years, (b) 9-10 years, and (c) 17-20 years. In each case nonretarded subjects had lower VE scores than their retarded counterparts. For the two other age categories (11-12 and 13-14 years), there was no significant difference between the VE scores of retarded and nonretarded subjects.

Hypothesis 5

There will be no significant relationship between median reaction time scores and the absolute value of median CE scores for any age category within either group: (a) retarded or (b) nonretarded.

Retarded subjects. Correlation coefficients for retarded subjects in each age category are presented in Table XIII. The Spearman rank order procedure used for correlating median reaction

TABLE XII

Summary Statistics for the Mann-Whitney-Wilcoxen Analysis Variable Error: Between Groups

| Comparison | | N | 7-8 | 9-10 | 11-12 | 13-14 | 17-20 | S/NS | Group Median Scores |
|---|---|---|---|---|---|---|---|---|---|
| R[a] | 7-8 | 8 | 91.00 | | | | | S | .2960 |
| NR[b] | 7-8 | 8 | 45.00 | | | | | | .0735 |
| R | 9-10 | 8 | | 91.00 | | | | S | .2155 |
| NR | 9-10 | 8 | | 45.00 | | | | | .0515 |
| R | 11-12 | 8 | | | 86.50 | | | NS | .1815 |
| NR | 11-12 | 8 | | | 49.50 | | | | .0490 |
| R | 13-14 | 8 | | | | 83.50 | | NS | .0695 |
| NR | 13-14 | 8 | | | | 52.50 | | | .0405 |
| R | 17-18 | 8 | | | | | 94.50 | S | .0720 |
| NR | 17-20 | 8 | | | | | 41.50 | | .0280 |

[a]R = Retarded

[b]NR = Nonretarded

TABLE XIII

Correlation Coefficients[a]--Retarded Subjects Median Reaction Time and Absolute Constant Error

| Age Category | Coefficient | Significance |
| --- | --- | --- |
| 7-8 | -.26 | .53 |
| 9-10 | -.62 | .10 |
| 11-12 | .45 | .32 |
| 13-14 | .17 | .69 |
| 17-20 | .45 | .32 |

[a]Spearman Rank Order.

time scores and the absolute value of median CE scores revealed no significant relationship for any of the age categories. However, a large negative correlation (-.62) was found for the 9-10 year old category. Although not significant at the .05 level, this relationship approached significance and indicated that as reaction time scores increased, the absolute value of median CE decreased. For remaining age categories, the strength of the correlation coefficients was weak and all but one (7-8 year olds) were positive.

Nonretarded subjects. Correlation coefficients for nonretarded subjects in each age category are presented in Table XIV The Spearman procedure used for the correlation of median reaction time scores and the absolute value of median CE scores revealed no significant relationship for any of the four youngest age groups. However, a significant ($p < .05$) positive correlation (.91) was obtained for the oldest age group (17-20 year olds). Therefore, Hypothesis 5 was rejected. For this age group, faster reaction times were associated with increased coincidence anticipation accuracy (i.e., less response bias). The correlation coefficients for these groups were all low and, with one exception (7-8 year olds), positive.

TABLE XIV

Correlation Coefficients[a]--Nonretarded Subjects: Median Reaction Time and Absolute Constant Error

| Age Category | Coefficient | Significance |
|---|---|---|
| 7-8 | -.14 | .74 |
| 9-10 | .36 | .39 |
| 11-12 | .29 | .49 |
| 13-14 | .45 | .26 |
| 17-20 | .91 | .01 |

[a]Spearman Rank Order.

# CHAPTER V

## DISCUSSION

Presented in this chapter is a discussion of the results which were reported in Chapter IV. The discussion is divided into three sections: (a) reaction time, (b) coincidence anticipation, and (c) the relationship of reaction time to coincidence anticipation. Within each section, separate discussions are devoted to the performance of (a) retarded and (b) nonretarded subjects. This discussion is limited to research in which (a) tasks were used which are similar to those used in the present study and/or (b) the sample selected consisted of subjects across an age range similar to that (7-20 years) chosen for the present study.

Low correlations between reaction time and movement time have typically been reported for some tasks requiring a rapid reaction which is followed immediately by a rapid movement (Henry, 1961; Smith, 1961). It might be argued that this low relationship is due to a differential "trading off" by subjects of reaction time for movement speed or vice versa. Thus, it is possible that in the present study some subjects may have focused more on moving rapidly (i.e., movement speed) from the initiation key to the response key (i.e., the target) which may have delayed their key release movement (i.e., reaction time). It was felt, however, that subjects in the present study (particularly those who were younger) would respond to the reaction time task with more sustained interest and enthusiasm if there was the perception that a task objective (i.e., hitting the response key and extinguishing the light) had been completed.

## Reaction Time

Retarded subjects. The Kruskal-Wallis one way analysis of variance revealed that age was a significant factor which was related to the reaction time performance of retarded subjects (Table I, page 50). This result appears to be consistent with that previously reported in the literature (Bankhead & MacKay, 1982; Ellis & Sloan, 1957). However, post hoc analysis of this age factor revealed that the three younger age categories exhibited similar reaction time performance (Table II, page 51). Bankhead and MacKay (1982) reported a significant difference between ages of each category (6-21 years) in their study. Thus, there was a general trend in decreasing reaction time over age in the present study, significant decreases were not evident for retarded subjects before early adolescence (13-14 years) as they were in the Bankhead and MacKay (1982) study.

Median reaction time scores for the three younger age categories were extremely slow (7-8 year olds = .592 sec, 9-10 year olds = .510 sec, 11-12 year olds = .475 sec), while the median scores of the two older age categories of the same group were considerably faster (13-14 year olds = .362 sec, 17-20 year olds = .312 sec) (Table II). There was a significant difference between the 11-12 year old and the 13-14 year old reaction time performance (Table II). This discrepancy in reaction time between the 11-12 and 13-14 year olds could be attributed to the difference in mean ages of the two groups. The mean age for the 11-12 year olds was 11 years, 7 months, with most of the subjects being closer to 11 years of age. The 13-14 year old category of the retarded group had a mean age of 14 years, 1 month; therefore, on the average, the 13-14 year olds were 30 months older than the next younger category of the retarded group. The three youngest age categories were closer in age to each adjacent group, thus lessening the possibility of difference in performance.

Confidentiality restrictions adopted by the school districts to protect the anonymity of individuals precluded identification of a person by specific IQ scores; therefore, the subjects were identified by an IQ range (50-69, inclusive). It is quite possible that some of the individuals in any or all of the retarded age categories were at either of two extremes within the specified retarded IQ range. It has been reported (Howe, 1959; Sloan, 1951) that motor skill and mental ability are related, with diminished mental ability being associated with lower motor performance. This factor may have been operating in the case of younger retarded subjects in the present study. It is also possible that older retarded subjects had a higher than usual mental age (which is not always the case).

For the retarded group, six of the eight in the youngest age category had reaction time performances which were characterized by a wide range of scores, indicating inconsistencies in response. Although the same was true of responses in the 9-10 year old category, the width of the range of scores within each age category decreased as age increased beyond that point (Table C-I, Appendix C). Bankhead and MacKay (1982) also found that as age increased, variability of scores within the age categories decreased. Lack of speed in response and variability in response may be an indication that the young subject has difficulty in determining when to make a response; thus contributing to longer decision time. Wade (1976) suggested that speed of response is affected by perception of signals and selection of the appropriate responses to those signals.

Nonretarded subjects. Analysis of the median reaction time scores of the nonretarded group revealed that as age increased, reaction time decreased (Table IV, page 54). This phenomenon has been reported by several researchers (Bankhead & MacKay, 1982; Eckert & Eichorn, 1977; Philip, 1934; Thomas et al., 1981). The statistical analysis indicated that the performance of the youngest age category was significantly different from that of the other age categories. The performance of the 9-10 year olds, 11-12 year olds, and the 13-14 year olds was similar and not significantly different from each other. Thus, the lack of significance indicated that significant decreases in reaction time occur before adolescence. Eckert & Eichorn (1977) reported that reaction time scores decreased up to age 14. Philip (1934) found that reaction time continued to decrease until age 16.

Although the median reaction time scores of these three age categories in the present study decreased as age increased, the decrease was not statistically significant. The 17-20 year olds, however, demonstrated significantly faster reaction time performances than that of all the groups. This is in agreement with Eckert and Eichorn (1977); however, Thomas et al. (1981) reported a significant difference in reaction time scores between each age category (7, 9, 11, 13, and 20 year olds).

As with the retarded group, there was not a completely uniform age spread across categories. The lack of significance between the reaction time performance for nonretarded subjects might have been because the nonretarded 9-10 year olds were closer in age to the 11-12 year olds and further away from the 7-8 year olds. It is possible that the lack of uniformity may have contributed to the pattern of differences in performance between the younger age categories.

Between group comparisons. In general, both retarded and non-retarded groups in the present study exhibited similar patterns or trends of performance, with the reaction time of the younger age categories being slower and more variable than that of the older age categories. Bankhead & MacKay (1982) used nonretarded and retarded subjects in a study in which they examined several variables, two of which were: (a) age related differences in reaction time performance and (b) differences in reaction time performance of retarded and non-retarded subjects. They reported similar results (i.e., similar pattern of performance) concerning the younger subjects within each IQ group to those results in the present study.

There were, however, in the present study significant differences in reaction time performance between several age categories of retarded and nonretarded subjects (Table IX, page 61). Past research has revealed that this difference has emerged in other samples of the two populations (Bankhead & MacKay, 1982; Baumeister & Kellas, 1968b; Gosling & Jenness, 1974; Krupski, 1977). Cross group comparisons in the present study revealed differences in performance only for the three youngest categories. In this respect, it appears that a pronounced developmental delay may be operating in the case of younger retarded subjects which contributes to impairments in performance. Most of the retarded children in the three younger categories: (a) attended a special school for mentally deficient individuals, or (b) were placed in separate classes in a regular school setting (i.e., were not mainstreamed). Thus, more severe retardation and lack of experience in physical activity could have accentuated the difference between the two IQ groups.

The reaction time performance of the two older categories of the retarded group was not significantly different from that of the two older categories of the nonretarded group (Table X, page 63). It is possible that for these age categories subjects in the retarded group were at the upper end of the IQ range. Most of these individuals had been mainstreamed into regular classes (where appropriate), and had participated in various types of physical activities (e.g., football, basketball, etc.). Thus, it is possible that for the older retarded individuals in this study, past experience or higher IQ served to reduce differences in their performance and that of nonretarded individuals. This lack of difference supports a projected notion of Bankhead & MacKay (1982). As a result of their research, Bankhead & MacKay (1982) have suggested that subaverage intelligence might not hinder the performance of retarded individuals, if their mental age is not too low and their chronological age is advanced.

Another possible explanation for the lack of difference in reaction time among the older groups of retarded and nonretarded subjects may be traced to the methodology used in subject selection. All subjects were randomly selected from the pool of those individuals who returned parental permission forms. In the process of random sampling, it is possible that one or more subjects might be chosen who demonstrate atypical performance for their group. Such may have been the case in the present study. The scores of two subjects in the nonretarded 13-14 year old category and that of one subject in the nonretarded 17-20 year old category were considerably slower than the median of each respective age category. Considering the sample sizes used in this experiment it is possible that the scores of these subjects might have contributed to the finding of no difference in the performance of retarded and nonretarded subjects in those age categories.

### Coincidence Anticipation--Constant Error (CE)

Retarded subjects. There was no significant difference in response bias (i.e., constant error) on the coincidence anticipation task for the different age categories in the retarded group. While each subject demonstrated his understanding of the task to the satisfaction of the experimenter, the performance of the two youngest groups appeared to be characterized by a more pronounced positive response (i.e., late responding) than was that of their older counterparts (Table C.V). Younger retarded subjects appeared to be able to track visual stimuli which was moving, but their scores indicated that they might have been less able to use the information to make their responses coincide with the arrival of the stimulus at the target point. As age increased (9-14 years) bias became less positive (i.e., not as late), but the difference between CE performance of the various age groups was not significant. The retarded group as a whole (73 percent) responded with a positive bias). There has been no report in the developmental literature as to the performance of retarded subjects using a Bassin Timer. Wade (1980), using a novel task to investigate task velocity (for description, see Chapter II) reported that age was not a factor which was significantly related to changes in CE.

Nonretarded subjects. Analysis of the CE data for the nonretarded group revealed results comparable to those for the retarded group. There was no significant difference in CE scores across age categories. Although there was no significant difference in scores, median CE decreased up to about 14 years of age. The nonretarded group generally responded with a less positive bias than the bias of the retarded group. Wade (1980) in his investigation of the effect of target velocity on coincidence anticipation performance reported that age was not a significant factor for nonretarded subjects who ranged in age from 8 years, 3 months to 12 years, 4 months.

The evidence in Wade's (1980) study is supported by the results in the present study; however, in contrast to the results of the present investigation, Thomas et al. (1981) reported a significant difference due to age. Haywood (1977) reported similar results to those of Thomas et al. (1981). Post hoc procedures used by Haywood (1980) revealed significantly more directional bias on the part of young (7 years, 6 months) children than older children (11 years, 8 months).

## Coincidence Anticipation--Variable Error (VE)

Retarded subjects. Analysis of the VE data for the retarded group revealed a significant difference due to age (Table V, page 56). For the most part as age increased VE decreased. The only exception to this trend occurred for the 11-12 year olds who were less variable in their performance than the 13-14 year olds; however, the difference in VE scores for these two groups was not significant. In an investigation of target velocity and target duration, Wade (1980) reported that there was a significant difference in VE due to age factors. Further analysis in Wade's (1980) study revealed that younger subjects were more variable than older subjects. In the present study the three youngest age categories demonstrated more within subject variability in error score than older categories. The VE of the oldest category was significantly different from that of the four younger categories. Thus, as in Wade's (1980) study, the present results suggested the developmental differences in the variability of coincidence anticipation responses.

Nonretarded subjects. A significant difference in VE across age was found for the nonretarded group (Table VII, page 59). The VE of the subjects in the oldest category was significantly less than that of the other four age categories. Thomas et al. (1981) also reported significant age effects for VE; furthermore, performance of the youngest age group (7 years, 6 months) was significantly less consistent than that of all other groups. In the present study, the four younger age categories performed with similar VE scores, as indicated by a nonsignificant difference in performance for these age groups. However, as age increased, VE scores generally decreased. The VE results from this study (particularly the lack of difference in performance among the younger groups) provided support for the notion that neither the retarded nor the nonretarded younger individual has yet formulated general strategies or plans of action to use when confronted with a novel task.

Between group comparisons. Although there was no group effect for CE, between group comparisons revealed several differences between the VE scores of retarded and nonretarded groups (Table VI, page 59). In both the youngest and the oldest age categories, the VE of retarded subjects was significantly higher than that of nonretarded subjects. In the 11-12 year old and 13-14 year old categories, retarded and nonretarded subjects performed with similar VE scores. The opposite extremes of VE performance were predictably evidenced by the youngest age category of the retarded group (which displayed the highest variability in scores) and by the oldest age category of the nonretarded group (which had the lowest VE). This contrast in performance seems to support the idea that older nonretarded individuals (higher mental age) are able to encode information and consistently respond with a selected motor plan, while young retarded subjects (low mental age) adopt different strategies from trial to trial.

### The Relationship of Reaction Time to Coincidence Anticipation Performance

Statistical analysis revealed a significant relationship between reaction time and absolute CE for only the oldest group of nonretarded subjects (Table XIV, page 69). The absence of a significant relationship for several of the younger age categories of nonretarded subjects does not conform to the result of earlier research (Thomas et al., 1981). Thomas et al. (1981) found a significant relationship between reaction time and coincidence anticipation performances for male subjects in the age categories of 7, 9, and 11 years, although the relationship became weaker with increasing age. Grose (1967) and Haywood (1977) reported a very low correlation (no significance) between reaction time and coincidence anticipation performance for adult subjects. Thomas et al. (1981) suggested that because young children have poor movement plans, their coincidence anticipation performance would depend on the response initiation phase (reaction time) as they processed the information necessary to perform the timing task. Consistent with this interpretation, Thomas et al. (1981) projected that slower reaction times in their study appeared to be paired with late coincidence anticipation responses for young males. This suggests that young children (lower mental ages) may view the coincident timing task in a different way than do adults (higher mental ages). For example, children who are impulsive may have faster reaction times and also have difficulty delaying their coincidence anticipation responses, resulting in more negative response bias.

Thomas et al. (1981) have suggested that this relationship weakens for older ages because of the development of better movement plans. However, in light of the results of the present study, it might be argued that although the older individual may have had a better motor plan, reaction time remained an important factor in coincidence anticipation performance, but in a slightly different way. Since decisions to respond in a timing situation must be made at least one reaction time before response initiation (Belisle, 1963; Schmidt, 1975), Schmidt (1975) suggested that a longer viewing time might be predicted to result in more accurate timing performance. This is because faster reaction time would presumably allow more stimulus information to be sampled before the response is initiated. Thus, subjects with faster reaction times would be afforded the opportunity to "wait longer" before initiating their coincidence movement, which might contribute to a more accurate timing of the stimulus. Conversely, those individuals with slower reaction times (i.e., high reaction time) might be forced to initiate their coincidence responses sooner, at the expense of accuracy.

The combination of small sample size and nature of the statistical measure used to determine the existence of the reaction time-coincidence anticipation relationship could also account for: (a) the pattern of correlation coefficients which were found and (b) the difference in results between this study and those of past research. The pattern of ranks for reaction time scores for subjects in the oldest nonretarded group was very similar to their pattern of ranks for coincidence anticipation scores.

There was no such pattern for any other age categories (except perhaps the 9-10 year olds in the retarded group). The ranking of scores for reaction time and coincidence anticipation error scores (for 9-10 year olds) was the most varied of all the age categories in both IQ groups. (The retarded 7-8 year olds had the same type of pattern but the correlation coefficient was not as high.) Because the Spearman procedure used rank order in the determination of the correlation coefficient, increasing the sample size for each category could affect the ranking of the scores within each category, which in turn would possibly affect the strength of the correlation coefficient.

Variability of scores within subjects might also have contributed to the pattern of correlations. In spite of efforts to make participation in the experiment appealing, some subjects may have lost interest because of: (a) the number of trials given and (b) simplicity of the tasks. For some subjects it was necessary, in the latter half of the trials, to verbally redirect their attention to the task before continuing with testing. Because of the size of the age range and IQ range, an attempt was made to keep the demands of the task as simple as possible. While this might have been necessary for the younger subjects, the older subjects might have viewed the task as too simple.

CHAPTER VI

# SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

## Summary

A major factor in the growth and development of an individual is proficiency in motor skills (Bruininks, 1974). In order to achieve proficient movement which is required by task demands, effective utilization and appropriate integration of certain motor components are necessary (Higgins, 1977). Adaptations to and adjustments in performance by mature and experienced performers seem to be automatic. The nonretarded individual appears to be increasingly adaptable to task demands during progressive stages of growth and development (Gesell, 1946; Kay, 1969). The purpose of this study was to examine a possible relationship between reaction time and coincidence anticipation across five age categories of retarded and nonretarded subjects. In addition, an attempt was made to determine whether one or all of the following existed: (a) a developmental pattern of decreasing reaction time and decreasing coincidence anticipation error scores with increasing age for both retarded and nonretarded samples, and (b) similarity in reaction time and coincidence anticipation performance between retarded and nonretarded samples at each age level.

Eighty male subjects who participated in this study were from one of two populations: (a) retarded (IQ range of 50-69, inclusive) and (b) nonretarded. Subjects were classified by one of the following age categories of growth and development: (a) 7 years, 0 months through 8 years, 10 months, (b) 9 years, 0 months through 10 years, 10 months, (c) 11 years, 0 months through 12 years, 10 months, (d) 13 years, 0 months through 14 years, 10 months, and (e) 17 years, 0 months through 20 years, 10 months. Each age category consisted of eight retarded and eight nonretarded subjects.

Two components of motor skills (a) reaction time and (b) coincidence anticipation (CE and VE) were examined by means of a simple visual reaction time apparatus and the Bassin Anticipation Timer, respectively. Variable foreperiods were randomly assigned to each of 20 trials for the reaction time task. A stimulus velocity of 134 cm/sec was used on each of the 20 trials which were administered on the coincidence anticipation task.

The raw data were organized by determining the median scores of the central 10 trials (i.e., trials 7-16) for each of the dependent measures: (a) reaction time score and (b) constant error (CE). One other dependent measure, variable error (VE), was calculated as the standard deviation of a subject's CE scores around his median CE for the 10 trials. Results of the F statistic revealed unequal variances for each of the three dependent variables and for subsequent log transformations which were performed on the data. Therefore, a Kruskal-Wallis one way analysis of variance was conducted on each of the dependent measures for each age category and IQ group. Post hoc procedures utilizing the Mann-Whitney-Wilcoxen technique were performed where appropriate to locate the source of significant difference.

The statistical analysis revealed that for the retarded sample the age effect was significant with the performance of the three youngest age groups significantly slower than that of the two oldest age groups. The age effect was also significant for the non-retarded group; however, the 7-8 year olds were significantly slower than the other four age categories. Although the median reaction time scores of the 9-10, 11-12, 13-14 year olds were not significantly different from one another, the performance of each was significantly different from that of the 17-20 year old category.

Median reaction time scores of the retarded group were significantly different from those of the nonretarded group. Further analysis revealed that this difference was located between the three youngest age categories. The performance of the two older groups was not significantly different.

For CE, there were no significant differences between age categories within either IQ group. For VE, there was a significant difference among age groups for both IQ groups. Generally, as age increased, VE decreased.

There was a significant difference in the VE performance of the retarded and nonretarded subjects. However, post hoc analyses revealed a significant difference between the IQ groups only for the 7-8 year olds, 9-10 year olds, and 17-20 year olds. There was no significant difference in the CE scores of the two groups for any age category.

The Spearman rank correlation procedure used for determining the extent of relationship between median reaction time scores and the absolute value of median CE scores revealed only one significant relationship for any age category in either of the two IQ groups and that was for the nonretarded 17-20 year olds. Although not significant at the .05 level, a large negative correlation (-.62) was found for the 9-10 year old category.

Although the results of this study may not have immediate practical application, the findings should be useful in the design of future training studies or in design of studies which investigate age differences between the variables: (a) reaction time and (b) coincidence anticipation.

## Conclusions

It is acknowledged that with a sample size of eight, caution must be used in drawing conclusions. However, it should be noted that in the present study 91 percent of the cases reported to be significant at the .05 alpha level were also significant at the .025 alpha level. The following conclusions have been made in light of the results from analysis of data in this study.

1. For both the retarded and nonretarded samples, reaction time decreased as age increasded. The most substantial decrease in reaction time scores occurred up to ages 13-14.
2. For each IQ group: (a) retarded and (b) nonretarded, VE decreased as a function of increasing age. Young (7-8 years and 9-10 years) retarded children exhibited more variability in performance than that of their

nonretarded counterparts and than that of the older age groups of both IQ groups.

3. Nonretarded individuals performed with faster reaction times than did their retarded counterparts.
4. Individuals from the nonretarded sample exhibited a more consistent coincidence anticipation performance than did their retarded counterparts.
5. For the tasks used in the present study there appears to be little relationship of reaction time to coincidence anticipation accuracy.

Recommendations

The following recommendations are made based on the results of this study:

1. For future studies of this nature, larger sample sizes are needed in order to permit broader inferences to be made based on the results.
2. For further examination of these two motor components (i.e., reaction time and coincidence anticipation) in which the identical tasks are used, modification of the type of response should be made. Both of the tasks need to have either a key depress or a key release response.
3. Further investigation is necessary before conclusions can be made concerning the exact nature of the relationship between an individual's reaction time and his ability to perform with accuracy on coincidence anticipation tasks.

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# APPENDIXES

APPENDIX A

Dear Parent:

Your child has an opportunity to participate in a project which will be conducted this school year at his/her school. My name is Margaret Woody, and I am a doctoral student at The University of Tennessee, in the Division of Physical Education. I hope that I can find out some things about certain physical skills that a person could use every day. The relationship between physical skills may be important in teaching physical education. The results of this project could provide help in teaching physical education to children and adults who have special needs.

I will look at these physical skills by observing the performance of the person during two different activities. I will make sure that the activity is clearly explained and that the child has an opportunity to ask any questions he/she wishes to ask. The activities will not be competitive, and there will be no pressure placed upon the child to finish the activities if he/she wishes to stop.

I have talked with the school principal about this project. He/She agrees that this type of activity should be studied. He/She and I have worked out a schedule in which all of the activities will be done in the school building and during school hours. This will not interfere with the plans of the teachers.

If you decide to let your child participate in these activities, please sign the permission form which is attached to this letter, and return the permission form to your child's teacher. I appreciate the time that you have taken to read this letter. If you have any questions, please feel free to contact me. The telephone numbers are listed below my name.

Sincerely yours,

Margaret E. Wooddy
Project Director

The University of Tennessee, Division of Physical Education
Knoxville, Tennessee 37996-2700
974-5111 or 521-6614

# Parental Permission for Participation

I give my permission for ______________________ to participate in the reaction time and object interception project of Margaret Wooddy which was described in her letter.

I understand that my child's participation in these two activities will be over a period of two days for approximately 15 minutes each day.

ACTIVITY ONE

The person will sit in a chair so that he/she can watch lights which will light up one after another. The person will press a button when he/she thinks the last light will light up.

ACTIVITY TWO

The person will sit in a chair and watch a small box which has a light bulb on top of it. When the light comes on, the person will press a button as fast as he/she can.

I understand that my child's name will not be included in any type of report. Any individual score or information which is collected will be kept confidential. I understand that I may withdraw my child from the project at any time without being penalized. My child may withdraw himself/herself from the project at any time, without being penalized.

I agree to allow the director of the project, Margaret Wooddy, to have the following information:

1. Chronological age

2. Handicapping condition

Participant's name: ______________________________

Participant's age: ______________ Birthdate: ______________

Signature of parent/guardian: ______________________________

Date: ______________

Project Director: Margaret E. Wooddy
University of Tennessee, Division of Physical Education
974-5111 or 521-6614

# APPENDIX B

Coincidence Anticipation Scores

1 2 3 4 5

EXPLAIN

| | |
|---|---|
| | 1 - |
| 2 - | 3 - |
| 4 - | 5 - |

| | |
|---|---|
| | 1 - |
| 2 - | 3 - |
| 4 - | 5 - |
| 6 - | 7 - |
| 8 - | 9 - |
| 10 - | 11 - |
| 12 - | 13 - |
| 14 - | 15 - |

Mdn.: ______ Mdn.: ______

Rank: ______ Rank: ______

Overall Mdn.: ______

Overall Rank: ______

Reaction Time Scores

1 2 3 4 5

EXPLAIN

| | | | |
|---|---|---|---|
| | | 1 | 1 |
| 2 | 2 | 1 | 3 |
| 3 | 4 | 1 | 5 |

| | | | |
|---|---|---|---|
| | | 3 | 1 |
| 2 | 2 | 1 | 3 |
| 3 | 4 | 2 | 5 |
| 2 | 6 | 3 | 7 |
| 1 | 8 | 2 | 9 |
| 1 | 10 | 1 | 11 |
| 3 | 12 | 1 | 13 |
| 3 | 14 | 1 | 15 |

Mdn.: ______ Mdn.: ______

Rank: ______ Rank: ______

Overall Mdn.: ______

Overall Rank: ______

Subject:

Birthdate:

Chronological Age Group:

| 7-8 | 9-10 | 11-12 | 13-14 | 17-21 |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

IQ Group: EMR 1 NR 2

Task Order: C/A, RT 1 RT, C/A 2

Hand Preference: R 1 L 2

Video Games: Yes 1 No 2

# APPENDIX C

TABLE C.I

Raw Data for Reaction Time: Retarded Subjects

| S | Trials 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Retarded 7-8 Year Olds | | | | | | | |
| 41 | 0.685 | 1.395 | 0.434 | 0.565 | 1.022 | 3.071 | 1.079 | 1.148 | 9.180 | 2.671 | 1.030 | | | | |
| 42 | 0.808 | 8.155 | 2.988 | 2.488 | 1.295 | 1.152 | 1.688 | 1.219 | 0.041 | 3.462 | 2.010 | 2.827 | 1.941 | 1.790 | 2.964 |
| 43 | 0.609 | 5.804 | 0.524 | 0.612 | 0.743 | 1.212 | 1.755 | 0.689 | 1.066 | 2.757 | 1.117 | 0.741 | 0.719 | 0.926 | 0.519 |
| 44 | 0.469 | 0.442 | 0.381 | 0.348 | 0.302 | 0.388 | 0.436 | 0.388 | 0.375 | 0.361 | 0.319 | 0.677 | 0.463 | 1.647 | 0.386 |
| 45 | 0.911 | 0.489 | 1.152 | 0.457 | 0.409 | 0.474 | 0.486 | 0.573 | 0.554 | 1.093 | 0.627 | 0.580 | 0.612 | 1.087 | 0.517 |
| 46 | 0.643 | 0.771 | 0.492 | 0.534 | 0.525 | 0.686 | 0.693 | 0.533 | 0.514 | 0.577 | 0.721 | 0.519 | 0.799 | 3.374 | 0.444 |
| 47 | 0.747 | 0.468 | 0.442 | 0.517 | 0.740 | 0.490 | 1.756 | 0.519 | 1.459 | 1.260 | 1.862 | 0.529 | 0.440 | 0.395 | 0.550 |
| 48 | 0.595 | 0.500 | 0.609 | 0.497 | 0.574 | 0.406 | 0.598 | 0.650 | 0.495 | 0.389 | 0.938 | 0.473 | 0.653 | 0.456 | 0.380 |
| | | | | | | | | Retarded 9-10 Year Olds | | | | | | | |
| 49 | 0.416 | 0.447 | 1.015 | 0.564 | 0.913 | 0.929 | 0.734 | 0.776 | 0.928 | 0.394 | 0.555 | 0.399 | 0.510 | 0.935 | 0.585 |
| 50 | 1.415 | 0.477 | 0.631 | 0.431 | 0.493 | 0.335 | 0.444 | 0.589 | 0.518 | 0.640 | 1.972 | 0.678 | 0.586 | 1.524 | 0.489 |
| 51 | 0.539 | 0.434 | 0.383 | 0.513 | 0.618 | 0.435 | 0.423 | 0.431 | 0.554 | 0.869 | 0.537 | 0.533 | 0.664 | 0.464 | 0.509 |
| 52 | 0.593 | 0.431 | 0.445 | 0.364 | 0.445 | 0.866 | 0.455 | 0.781 | 0.866 | 0.404 | 0.725 | 0.612 | 3.235 | 0.520 | 0.659 |
| 53 | 0.519 | 0.693 | 0.503 | 0.653 | 0.554 | 0.488 | 0.701 | 0.384 | 0.579 | 0.432 | 0.563 | 0.616 | 0.453 | 0.535 | 0.395 |
| 54 | 0.411 | 0.366 | 0.507 | 0.417 | 0.414 | 0.409 | 0.464 | 0.510 | 0.515 | 0.417 | 0.483 | 0.577 | 0.446 | 0.389 | 0.780 |
| 55 | 0.626 | 0.520 | 0.776 | 1.110 | 0.740 | 0.652 | 1.002 | 1.272 | 0.626 | 0.751 | 0.537 | 1.413 | 1.010 | 0.807 | 1.206 |
| 56 | 0.621 | 0.455 | 0.321 | 0.477 | 0.573 | 0.441 | 0.516 | 0.498 | 0.725 | 0.569 | 0.394 | 0.777 | 0.728 | 0.484 | 0.708 |
| | | | | | | | | Retarded 11-12 Year Olds | | | | | | | |
| 57 | 0.272 | 0.325 | 0.300 | 0.353 | 0.284 | 0.391 | 0.327 | 0.286 | 0.615 | 0.478 | 0.355 | 0.305 | 0.469 | 0.361 | 0.457 |
| 58 | 0.415 | 2.092 | 1.883 | 1.858 | 0.531 | 1.337 | 0.494 | 1.168 | 0.707 | 1.088 | 0.864 | 2.733 | 1.573 | 0.968 | 0.487 |
| 59 | 0.584 | 0.726 | 0.537 | 0.678 | 0.749 | 0.794 | 0.457 | 0.474 | 0.681 | 0.530 | 0.477 | 0.795 | 0.555 | 0.660 | 0.991 |
| 60 | 0.323 | 0.282 | 0.348 | 0.376 | 0.304 | 0.324 | 0.303 | 0.339 | 0.322 | 0.298 | 0.395 | 0.380 | 0.460 | 0.294 | 0.381 |
| 61 | 0.509 | 0.640 | 0.388 | 1.156 | 0.424 | 0.915 | 0.652 | 0.501 | 0.681 | 0.527 | 0.559 | 0.597 | 0.739 | 0.563 | 0.393 |
| 62 | 1.261 | 0.393 | 0.591 | 0.466 | 0.557 | 0.413 | 0.286 | 0.406 | 0.508 | 0.664 | 0.585 | 0.461 | 0.951 | 0.473 | 0.444 |
| 63 | 0.320 | 0.457 | 0.357 | 0.365 | 0.346 | 0.351 | 0.393 | 0.605 | 0.463 | 0.395 | 0.382 | 0.327 | 0.518 | 0.313 | 0.374 |
| 64 | 0.512 | 0.396 | 0.463 | 0.395 | 0.370 | 2.301 | 0.730 | 0.465 | 0.463 | 0.471 | 0.601 | 0.405 | 0.614 | 0.731 | 0.535 |

TABLE C.I (Continued)

| S | Trials 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Retarded 13-14 Year Olds | | | | | | | | | | | | | | |
| 65 | 0.332 | 0.327 | 0.325 | 0.466 | 0.349 | 0.359 | 0.338 | 0.334 | 0.333 | 0.347 | 0.324 | 0.323 | 0.303 | 0.311 | 0.391 |
| 66 | 0.349 | 0.318 | 0.288 | 0.356 | 0.385 | 0.339 | 0.394 | 0.254 | 0.345 | 0.446 | 0.356 | 0.348 | 0.345 | 0.332 | 0.453 |
| 67 | 0.319 | 0.327 | 0.373 | 0.275 | 0.281 | 0.344 | 0.319 | 0.270 | 0.264 | 0.247 | 0.317 | 0.346 | 0.293 | 0.360 | 0.295 |
| 68 | 0.418 | 0.302 | 0.426 | 0.461 | 0.597 | 0.304 | 0.367 | 0.417 | 0.375 | 0.434 | 0.377 | 0.549 | 0.362 | 0.373 | 0.614 |
| 69 | 0.292 | 0.258 | 0.457 | 0.307 | 0.300 | 0.595 | 0.318 | 0.355 | 0.302 | 0.542 | 0.313 | 0.324 | 0.561 | 0.286 | 0.401 |
| 70 | 0.397 | 0.339 | 0.375 | 0.423 | 0.390 | 0.381 | 0.377 | 0.412 | 0.390 | 0.554 | 0.475 | 0.421 | 0.370 | 0.379 | 0.425 |
| 71 | 0.340 | 0.373 | 0.317 | 0.428 | 0.361 | 0.346 | 0.406 | 0.374 | 0.351 | 0.495 | 1.163 | 0.385 | 0.296 | 0.322 | 0.435 |
| 72 | 0.412 | 0.373 | 0.487 | 0.517 | 0.494 | 0.412 | 0.444 | 0.501 | 0.447 | 0.381 | 0.417 | 0.427 | 0.473 | 0.400 | 0.890 |
| | Retarded 17-20 Year Olds | | | | | | | | | | | | | | |
| 73 | 0.363 | 0.296 | 0.310 | 0.429 | 0.300 | 0.418 | 0.421 | 0.286 | 0.318 | 0.295 | 0.278 | 0.538 | 0.303 | 0.278 | 0.294 |
| 74 | 0.393 | 0.392 | 0.354 | 0.361 | 0.443 | 0.347 | 0.379 | 0.374 | 0.380 | 0.348 | 0.359 | 0.395 | 0.384 | 0.374 | 0.513 |
| 75 | 0.295 | 0.232 | 0.238 | 0.292 | 0.284 | 0.245 | 0.299 | 0.396 | 0.282 | 0.306 | 0.452 | 0.310 | 0.291 | 0.288 | 0.266 |
| 76 | 0.341 | 0.298 | 0.295 | 0.373 | 0.362 | 0.565 | 0.348 | 0.645 | 0.295 | 0.502 | 0.308 | 0.327 | 0.425 | 0.386 | 0.487 |
| 77 | 0.461 | 0.354 | 0.349 | 0.265 | 0.317 | 0.364 | 0.268 | 0.402 | 0.276 | 0.276 | 0.291 | 0.263 | 0.313 | 0.205 | 0.273 |
| 78 | 0.267 | 0.255 | 0.276 | 0.243 | 0.227 | 0.257 | 0.248 | 0.209 | 0.233 | 0.239 | 0.229 | 0.285 | 0.226 | 0.248 | 0.336 |
| 79 | 0.383 | 0.373 | 0.310 | 0.323 | 0.304 | 0.338 | 0.320 | 0.505 | 0.382 | 0.373 | 0.308 | 0.372 | 0.287 | 0.347 | 0.308 |
| 80 | 0.367 | 0.314 | 0.315 | 0.322 | 0.280 | 0.323 | 0.304 | 0.373 | 0.315 | 0.594 | 0.346 | 0.343 | 0.351 | 0.457 | 0.300 |

TABLE C.II

Raw Data for Constant Error: Retarded Subjects

| S | Trials 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Retarded 7-8 Year Olds | | | | | | | | |
| 41 | +0.199 | +1.186 | +1.051 | -0.678 | +0.020 | +0.148 | +0.962 | +0.178 | -1.485 | +0.340 | -1.421 | +0.462 | | | |
| 42 | +0.376 | +0.303 | +0.349 | +0.732 | +0.238 | +0.745 | +0.613 | +0.292 | -0.067 | +0.182 | +0.007 | +0.007 | +0.174 | -0.030 | -0.022 |
| 43 | +0.101 | -0.121 | -0.152 | +0.071 | +0.102 | -0.176 | +0.115 | -0.111 | -0.174 | +0.012 | +0.166 | +0.157 | +0.045 | +0.038 | +0.076 |
| 44 | -0.162 | +0.309 | +0.186 | +0.172 | +0.081 | +0.439 | +0.256 | +0.131 | +0.255 | +0.114 | +0.149 | -0.159 | +0.293 | +0.264 | +0.272 |
| 45 | +0.290 | +0.125 | +0.221 | -0.213 | +0.411 | +0.351 | +1.160 | +0.435 | +0.387 | +1.045 | +0.569 | +0.260 | +0.250 | +0.738 | +0.475 |
| 46 | -0.070 | -0.172 | -0.093 | -0.627 | +0.099 | -0.856 | +0.075 | -0.144 | +0.054 | -0.089 | -0.290 | +0.059 | -0.206 | -0.981 | -0.404 |
| 47 | +0.158 | -0.024 | +0.206 | +0.200 | -0.058 | +0.191 | +0.260 | +0.017 | -0.119 | -0.032 | +0.050 | +0.211 | +0.394 | -0.033 | -0.143 |
| 48 | -0.092 | +0.212 | +0.099 | +0.201 | +0.226 | +0.157 | +0.351 | +0.129 | -1.395 | +0.124 | +0.208 | +0.248 | +0.410 | +0.289 | +0.330 |
| | | | | | | | Retarded 9-10 Year Olds | | | | | | | | |
| 49 | +0.188 | -0.069 | -0.223 | +0.117 | +0.021 | +0.149 | +0.150 | -0.113 | +0.059 | +0.093 | -0.181 | -0.191 | -0.014 | +0.077 | -0.179 |
| 50 | +0.247 | +0.050 | +0.774 | +0.277 | -0.002 | -0.067 | +1.103 | -0.747 | +0.162 | +0.413 | +0.332 | -0.998 | +0.156 | +0.108 | -0.694 |
| 51 | +0.353 | +0.231 | +0.180 | +0.105 | +0.173 | +0.166 | +0.205 | +0.220 | +0.105 | +0.147 | +0.103 | +0.179 | +0.214 | +0.090 | +0.164 |
| 52 | +0.415 | +0.283 | +0.779 | +0.891 | +0.062 | +0.073 | +0.328 | +0.289 | +0.435 | +0.520 | +0.154 | +0.269 | +0.228 | +0.206 | +0.638 |
| 53 | +0.084 | -0.723 | -0.300 | +0.005 | +0.287 | +0.071 | +0.082 | -0.024 | -0.166 | -0.352 | +0.074 | -0.112 | +0.109 | -0.074 | +0.064 |
| 54 | +0.168 | +0.271 | -0.013 | +0.342 | +0.312 | +0.533 | +0.171 | +0.237 | +0.231 | +0.264 | +0.114 | +0.060 | +0.212 | +0.421 | +0.345 |
| 55 | +0.803 | +0.116 | +0.316 | +0.489 | +0.924 | -0.442 | +1.743 | +0.045 | -0.765 | +0.389 | +0.141 | +0.133 | -0.592 | -0.013 | -0.797 |
| 56 | -0.134 | -0.015 | +0.160 | -0.025 | -0.065 | -0.080 | -0.503 | -0.137 | +0.079 | -0.001 | -0.114 | -0.039 | +0.042 | -0.065 | -0.107 |
| | | | | | | | Retarded 11-12 Year Olds | | | | | | | | |
| 57 | +0.272 | +0.103 | +0.290 | +0.090 | +0.156 | +0.324 | +0.254 | +0.169 | +0.181 | +0.270 | -0.007 | +0.123 | -0.015 | +0.189 | +0.240 |
| 58 | +0.093 | +0.316 | -0.257 | -0.211 | +0.589 | +0.405 | +0.467 | +0.085 | +0.083 | +0.216 | +0.314 | +0.136 | +0.162 | +0.508 | +0.208 |
| 59 | +0.244 | +0.105 | +0.843 | +0.403 | -2.032 | +0.270 | -1.799 | +0.090 | +0.580 | +0.524 | -0.659 | +0.500 | +0.264 | +0.745 | +0.534 |
| 60 | +0.024 | -0.004 | +0.041 | +0.105 | +0.070 | +0.103 | +0.067 | +0.117 | +0.073 | +0.050 | +0.148 | +0.110 | +0.030 | -0.035 | -0.038 |
| 61 | -0.088 | -0.011 | -0.555 | -0.055 | -0.220 | +0.036 | -0.030 | +0.049 | +0.026 | -0.033 | -0.166 | -0.007 | +0.006 | -0.049 | +0.006 |
| 62 | +0.454 | -0.231 | -0.278 | +0.007 | +0.061 | +0.077 | =0.058 | -0.660 | -0.365 | -0.499 | +0.193 | -0.175 | -0.802 | -0.182 | -0.501 |
| 63 | +0.097 | +0.039 | -0.018 | +0.055 | +0.074 | +0.130 | +0.044 | +0.027 | +0.002 | +0.003 | +0.100 | +0.102 | +0.079 | +0.096 | +0.004 |
| 64 | +0.172 | +0.088 | +0.192 | +0.502 | +0.215 | -0.257 | +1.006 | +0.643 | +0.992 | =1.134 | +0.068 | +0.106 | +0.039 | -0.415 | +0.797 |

TABLE C.II (Continued)

| S | Trials 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retarded 13-14 Year Olds | | | | | | | | | | | | | | | |
| 65 | -0.070 | +0.119 | +0.068 | +0.116 | +0.029 | +0.034 | +0.028 | +0.131 | +0.005 | +0.100 | +0.042 | +0.120 | +0.051 | +0.054 | +0.071 |
| 66 | -0.783 | +0.155 | +0.139 | +0.082 | +0.055 | +0.383 | +0.006 | +0.174 | +0.185 | +0.296 | +0.381 | +0.384 | +0.133 | +0.220 | +0.235 |
| 67 | +0.102 | +0.063 | +0.081 | +0.152 | +0.130 | +0.111 | +0.093 | +0.070 | +0.140 | +0.077 | +0.104 | +0.122 | +0.081 | +0.068 | +0.083 |
| 68 | -0.163 | -0.240 | +0.070 | +0.027 | +0.004 | -0.061 | -0.232 | +0.116 | -0.056 | +0.031 | -0.131 | -0.074 | -0.074 | -0.121 | -0.130 |
| 69 | -0.110 | -0.105 | -0.052 | +0.037 | -0.172 | -0.140 | -0.226 | -0.088 | -0.224 | +0.018 | -0.081 | -0.055 | -0.277 | -2.033 | -0.015 |
| 70 | +0.300 | +0.193 | +0.178 | +0.175 | +0.192 | +0.187 | +0.190 | +0.121 | +0.159 | +0.254 | +0.207 | +0.125 | +0.290 | +0.194 | +0.045 |
| 71 | -0.203 | +0.000 | +0.074 | -0.034 | -0.035 | +0.104 | +0.045 | -0.009 | -0.005 | +0.008 | -0.077 | +0.072 | +0.030 | +0.105 | +0.022 |
| 72 | -0.009 | -0.049 | -0.127 | -0.2±0 | -0.132 | -0.447 | -0.069 | -0.172 | -0.319 | -0.051 | -0.063 | -0.082 | -0.188 | -0.178 | -0.049 |
| Retarded 17-20 Year Olds | | | | | | | | | | | | | | | |
| 73 | -0.133 | -0.059 | -0.050 | -0.062 | -0.267 | -0.046 | +0.076 | -0.002 | +0.023 | -0.090 | -0.015 | -0.019 | +0.040 | +0.050 | +0.015 |
| 74 | -0.001 | +0.038 | -0.017 | +0.125 | +0.088 | +0.042 | +0.152 | +0.068 | +0.089 | +0.089 | +0.084 | +0.131 | +0.046 | +0.063 | +0.112 |
| 75 | +0.034 | +0.052 | -0.101 | +0.164 | -0.091 | +0.180 | +0.086 | -0.064 | +0.032 | -0.069 | +0.131 | +0.072 | +0.069 | -0.268 | +0.065 |
| 76 | +0.263 | +0.066 | +0.199 | +0.141 | +0.181 | +0.152 | +0.298 | +0.113 | +0.124 | +0.064 | +0.045 | +0.142 | +0.089 | +0.048 | -0.093 |
| 77 | +0.129 | +0.179 | -0.001 | -0.063 | +0.162 | +0.110 | +0.007 | +0.070 | +0.200 | +0.011 | +0.025 | +0.012 | +0.131 | +0.117 | +0.086 |
| 78 | -0.019 | +0.005 | +0.059 | +0.047 | +0.037 | +0.051 | +0.040 | +0.053 | +0.012 | +0.071 | +0.118 | +0.077 | +0.114 | +0.040 | -0.072 |
| 79 | +0.055 | +0.057 | -0.068 | -0.113 | -0.062 | +0.050 | +0.022 | +0.029 | -0.001 | +0.127 | +0.085 | +0.067 | +0.041 | -0.019 | -0.004 |
| 80 | -0.262 | +0.089 | +0.101 | +0.063 | +0.088 | +0.156 | +0.033 | +0.087 | +0.200 | +0.068 | +0.110 | -0.170 | +0.028 | +0.180 | +0.109 |

TABLE C.III

Raw Data for Reaction Time: Nonretarded Subjects

| S | Trials 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Nonretarded 7-8 Year Olds | | | | | | | |
| 01 | 0.366 | 0.350 | 0.560 | 0.379 | 0.497 | 0.376 | 0.415 | 0.404 | 0.320 | 0.364 | 0.385 | 0.348 | 0.352 | 0.361 | 0.543 |
| 02 | 0.475 | 0.349 | 0.400 | 0.482 | 0.273 | 0.091 | 0.603 | 0.534 | 0.466 | 0.465 | 0.766 | 0.371 | 0.376 | 0.591 | 0.399 |
| 03 | 0.371 | 0.406 | 0.392 | 0.536 | 0.361 | 0.411 | 0.369 | 0.385 | 0.640 | 0.367 | 0.400 | 0.416 | 0.407 | 0.478 | 0.674 |
| 04 | 0.384 | 0.310 | 0.378 | 0.408 | 0.537 | 0.559 | 0.338 | 0.495 | 0.343 | 0.382 | 0.445 | 0.281 | 0.276 | 0.354 | 0.667 |
| 05 | 0.394 | 0.565 | 0.432 | 0.464 | 0.600 | 0.403 | 0.753 | 0.560 | 0.442 | 0.684 | 0.574 | 0.631 | 0.631 | 0.823 | 0.474 |
| 06 | 0.327 | 0.340 | 0.391 | 0.325 | 0.349 | 0.446 | 0.578 | 0.360 | 0.426 | 0.396 | 0.338 | 0.315 | 0.336 | 0.309 | 0.370 |
| 07 | 0.351 | 0.293 | 0.553 | 0.380 | 0.385 | 0.288 | 0.308 | 0.530 | 0.348 | 0.519 | 0.670 | 0.462 | 0.329 | 0.307 | 0.576 |
| 08 | 0.394 | 0.362 | 0.351 | 0.452 | 0.316 | 0.295 | 0.449 | 0.405 | 0.370 | 0.346 | 0.285 | 0.313 | 0.349 | 0.311 | 0.441 |
| | | | | | | | | Nonretarded 9-10 Year Olds | | | | | | | |
| 09 | 0.330 | 0.352 | 0.324 | 0.412 | 0.458 | 0.328 | 0.614 | 0.336 | 0.384 | 0.411 | 0.334 | 0.350 | 0.312 | 0.340 | 0.516 |
| 10 | 0.309 | 0.330 | 0.300 | 0.329 | 0.341 | 0.327 | 0.371 | 0.522 | 0.460 | 0.465 | 0.306 | 0.329 | 0.343 | 0.453 | 0.290 |
| 11 | 0.336 | 0.301 | 0.297 | 0.350 | 0.336 | 0.356 | 0.328 | 0.326 | 0.331 | 0.297 | 0.351 | 0.340 | 0.300 | 0.300 | 0.486 |
| 12 | 0.370 | 0.329 | 0.405 | 0.291 | 0.401 | 0.335 | 0.290 | 0.592 | 0.651 | 0.656 | 0.470 | 0.282 | 0.307 | 0.329 | 0.326 |
| 13 | 0.336 | 0.290 | 0.309 | 0.294 | 0.328 | 0.285 | 0.301 | 0.569 | 0.326 | 0.304 | 0.349 | 0.300 | 0.287 | 0.454 | 0.373 |
| 14 | 0.309 | 0.490 | 0.313 | 0.280 | 0.279 | 0.322 | 0.272 | 0.263 | 0.234 | 0.287 | 0.265 | 0.319 | 0.331 | 0.279 | 0.477 |
| 15 | 0.331 | 0.447 | 0.483 | 0.339 | 0.377 | 0.361 | 0.409 | 0.389 | 0.396 | 0.363 | 0.386 | 0.372 | 0.377 | 0.338 | 0.356 |
| 16 | 0.357 | 0.349 | 0.827 | 0.282 | 0.536 | 0.341 | 0.322 | 0.334 | 0.322 | 0.658 | 0.437 | 0.290 | 0.351 | 0.281 | 0.351 |
| | | | | | | | | Nonretarded 11-12 Year Olds | | | | | | | |
| 17 | 0.397 | 0.334 | 0.334 | 0.391 | 0.315 | 0.718 | 0.479 | 0.451 | 0.374 | 0.542 | 0.534 | 0.442 | 0.393 | 0.361 | 0.433 |
| 18 | 0.518 | 0.486 | 0.325 | 0.488 | 0.670 | 0.363 | 0.301 | 0.318 | 0.336 | 0.258 | 0.296 | 0.359 | 0.382 | 0.292 | 0.398 |
| 19 | 0.324 | 0.306 | 0.264 | 0.276 | 0.339 | 0.328 | 0.297 | 0.302 | 0.377 | 0.420 | 0.270 | 0.365 | 0.464 | 0.380 | 0.337 |
| 20 | 0.255 | 0.312 | 0.278 | 0.282 | 0.263 | 0.337 | 0.307 | 0.518 | 0.309 | 0.265 | 0.256 | 0.258 | 0.269 | 0.286 | 0.309 |
| 21 | 0.376 | 0.325 | 0.329 | 0.345 | 0.342 | 0.299 | 0.322 | 0.350 | 0.295 | 0.304 | 0.307 | 0.336 | 0.317 | 0.308 | 0.342 |
| 22 | 0.286 | 0.253 | 0.251 | 0.276 | 0.253 | 0.264 | 0.286 | 0.306 | 0.298 | 0.396 | 0.306 | 0.260 | 0.331 | 0.314 | 0.294 |
| 23 | 0.283 | 0.270 | 0.271 | 0.275 | 0.317 | 0.282 | 0.332 | 0.259 | 0.354 | 0.289 | 0.278 | 0.295 | 0.272 | 0.348 | 0.270 |
| 24 | 0.306 | 0.227 | 0.324 | 0.293 | 0.353 | 0.344 | 0.286 | 0.304 | 0.311 | 0.267 | 0.266 | 0.275 | 0.312 | 0.343 | 0.273 |

TABLE C.III (Continued)

| S | Trials 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nonretarded 13-14 Year Olds | | | | | | | | | | | | | | |
| 25 | 0.344 | 0.308 | 0.399 | 0.325 | 0.340 | 0.355 | 0.278 | 0.498 | 0.363 | 0.305 | 0.299 | 0.294 | 0.568 | 0.373 | 0.317 |
| 26 | 0.385 | 0.308 | 0.324 | 0.362 | 0.325 | 0.313 | 0.307 | 0.342 | 0.405 | 0.329 | 0.393 | 0.343 | 0.322 | 0.313 | 0.301 |
| 27 | 0.302 | 0.336 | 0.339 | 0.289 | 0.429 | 0.313 | 0.296 | 0.320 | 0.295 | 0.318 | 0.331 | 0.313 | 0.321 | 0.303 | 0.626 |
| 28 | 0.294 | 0.280 | 0.320 | 0.286 | 0.299 | 0.539 | 0.298 | 0.299 | 0.287 | 0.316 | 0.348 | 0.307 | 0.301 | 0.282 | 0.280 |
| 29 | 0.284 | 0.427 | 0.346 | 0.304 | 0.342 | 0.276 | 0.384 | 0.386 | 0.288 | 0.363 | 0.369 | 0.369 | 0.433 | 0.276 | 0.331 |
| 30 | 0.312 | 0.285 | 0.335 | 0.298 | 0.390 | 0.314 | 0.303 | 0.334 | 0.332 | 0.335 | 0.324 | 0.342 | 0.368 | 0.340 | 0.416 |
| 31 | 0.338 | 0.344 | 0.355 | 0.339 | 0.338 | 0.374 | 0.378 | 0.322 | 0.302 | 0.353 | 0.566 | 0.281 | 0.350 | 0.317 | 0.409 |
| 32 | 0.332 | 0.333 | 0.298 | 0.337 | 0.294 | 0.296 | 0.312 | 0.288 | 0.296 | 0.316 | 0.317 | 0.310 | 0.295 | 0.270 | 0.305 |
| | Nonretarded 17-20 Year Olds | | | | | | | | | | | | | | |
| 33 | 0.268 | 0.292 | 0.320 | 0.354 | 0.323 | 0.348 | 0.297 | 0.319 | 0.354 | 0.257 | 0.469 | 0.297 | 0.383 | 0.320 | 0.320 |
| 34 | 0.316 | 0.331 | 0.286 | 0.261 | 0.258 | 0.267 | 0.281 | 0.394 | 0.289 | 0.311 | 0.258 | 0.293 | 0.285 | 0.254 | 0.236 |
| 35 | 0.260 | 0.248 | 0.261 | 0.254 | 0.273 | 0.227 | 0.241 | 0.280 | 0.226 | 0.224 | 0.275 | 0.203 | 0.262 | 0.257 | 0.244 |
| 36 | 0.280 | 0.258 | 0.284 | 0.268 | 0.274 | 0.259 | 0.281 | 0.328 | 0.268 | 0.303 | 0.282 | 0.248 | 0.296 | 0.290 | 0.297 |
| 37 | 0.298 | 0.333 | 0.289 | 0.280 | 0.300 | 0.295 | 0.304 | 0.305 | 0.286 | 0.347 | 0.293 | 0.247 | 0.340 | 0.316 | 0.269 |
| 38 | 0.244 | 0.251 | 0.281 | 0.287 | 0.294 | 0.242 | 0.286 | 0.351 | 0.430 | 0.337 | 0.267 | 0.296 | 0.283 | 0.328 | 0.388 |
| 39 | 0.319 | 0.273 | 0.320 | 0.288 | 0.270 | 0.312 | 0.302 | 0.449 | 0.255 | 0.295 | 0.268 | 0.282 | 0.417 | 0.281 | 0.338 |
| 40 | 0.247 | 0.222 | 0.252 | 0.249 | 0.238 | 0.237 | 0.246 | 0.250 | 0.231 | 0.256 | 0.333 | 0.262 | 0.267 | 0.344 | 0.312 |

TABLE C.IV

Raw Data for Constant Error: Nonretarded Subjects

| S | Trials 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Nonretarded 7-8 Year Olds | | | | | | | |
| 01 | +0.115 | +0.065 | +0.079 | +0.105 | +0.078 | +0.039 | +0.162 | +0.166 | -0.083 | +0.015 | +0.117 | +0.069 | +0.008 | -0.016 | +0.143 |
| 02 | -0.001 | +0.081 | -0.928 | +0.108 | +0.080 | -0.276 | +0.057 | +0.021 | +0.039 | +0.077 | -0.201 | -0.037 | +0.180 | +0.086 | 0.103 |
| 03 | +0.140 | +0.026 | -0.094 | +0.034 | +0.100 | +0.096 | +0.065 | -0.158 | +0.033 | -0.052 | +0.029 | +0.033 | +0.153 | +0.085 | -0.155 |
| 04 | +0.049 | +0.207 | +0.146 | +0.102 | +0.126 | +0.110 | +0.040 | +0.127 | +0.048 | +0.095 | +0.136 | +0.095 | +0.013 | +0.075 | +0.127 |
| 05 | +0.052 | +0.123 | -0.167 | +0.096 | +0.142 | +0.001 | +0.090 | +0.071 | +0.299 | +0.151 | +0.274 | =0.038 | +0.118 | +0.067 | +0.244 |
| 06 | -0.083 | +0.105 | +0.111 | +0.023 | +0.007 | -0.079 | +0.046 | +0.070 | +0.093 | +0.145 | -0.028 | -0.009 | +0.086 | +0.052 | -0.018 |
| 07 | +0.019 | +0.136 | -0.038 | +0.043 | +0.189 | +0.135 | +0.001 | +0.058 | +0.070 | +0.091 | +0.062 | +0.043 | +0.133 | +0.073 | +0.071 |
| 08 | +0.132 | +0.052 | +0.183 | +0.236 | -0.152 | +0.109 | +0.175 | +0.027 | +0.161 | -0.113 | +0.152 | +0.140 | +0.026 | +0.197 | +0.164 |
| | | | | | | | | Nonretarded 9-10 Year Olds | | | | | | | |
| 09 | +0.110 | +0.158 | +0.121 | +0.077 | +0.075 | +0.190 | +0.121 | +0.093 | +0.181 | +0.148 | +0.204 | +0.099 | +0.061 | +0.147 | +0.120 |
| 10 | +0.077 | +0.041 | +0.095 | +0.026 | +0.123 | -0.006 | +0.066 | +0.026 | +0.066 | +0.106 | +0.080 | +0.045 | +0.084 | +0.058 | +0.099 |
| 11 | +0.065 | +0.004 | -0.057 | -0.004 | +0.096 | -0.101 | +0.001 | +0.002 | -0.008 | -0.061 | +0.012 | +0.057 | -0.139 | -0.061 | -0.018 |
| 12 | +0.014 | +0.003 | +0.073 | -0.102 | +0.035 | +0.109 | +0.038 | +0.274 | +0.029 | +0.090 | +0.039 | +0.086 | +0.073 | +0.004 | +0.056 |
| 13 | +0.083 | +0.037 | +0.051 | +0.051 | +0.074 | +0.051 | +0.092 | -0.003 | +0.029 | +0.004 | +0.002 | +0.105 | +0.066 | -0.054 | +0.000 |
| 14 | -0.034 | +0.041 | -0.209 | +0.068 | +0.123 | -0.002 | +0.092 | -0.097 | +0.063 | +0.048 | +0.054 | +0.012 | +0.051 | -0.054 | +0.060 |
| 15 | +0.134 | +0.106 | +0.097 | +0.111 | +0.129 | +0.133 | +0.203 | -0.230 | +0.104 | +0.052 | +0.228 | +0.173 | +0.059 | +0.074 | +0.007 |
| 16 | +0.058 | +0.099 | +0.035 | +0.056 | +0.031 | +0.033 | +0.088 | +0.058 | +0.071 | -0.076 | -0.006 | +0.029 | -0.077 | +0.043 | +0.030 |
| | | | | | | | | Nonretarded 11-12 Year Olds | | | | | | | |
| 17 | +0.058 | +0.087 | +0.117 | +0.046 | +0.102 | +0.149 | +0.169 | +0.045 | +0.123 | +0.085 | +0.018 | +0.101 | +0.480 | +0.053 | +0.071 |
| 18 | -0.054 | +0.066 | +0.067 | +0.014 | +0.036 | +0.103 | +0.167 | +0.090 | +0.085 | +0.017 | -0.042 | +0.062 | +0.101 | +0.028 | +0.109 |
| 19 | +0.031 | +0.030 | +0.061 | -0.026 | -0.045 | -0.005 | -0.021 | +0.003 | -0.015 | +0.036 | +0.002 | +0.016 | -0.054 | +0 009 | +0.076 |
| 20 | +0.088 | +0.089 | -0.035 | +0.080 | +0.054 | -0.037 | +0.018 | -0.002 | +0.107 | -0.097 | -0.007 | +0.035 | +0.028 | -0.002 | +0.008 |
| 21 | +0.091 | -0.002 | +0.001 | +0.003 | +0.005 | -0.120 | -0.051 | -0.151 | +0.040 | -0.212 | +0.015 | +0.016 | +0.020 | +0.035 | +0.038 |
| 22 | +0.051 | +0.033 | +0.046 | +0.120 | +0.140 | +0.052 | +0.038 | +0.057 | +0.056 | -0.006 | +0.075 | +0.040 | -0.033 | +0.020 | +0.047 |
| 23 | +0.008 | +0.079 | +0.108 | +0.008 | +0.032 | +0.006 | +0.054 | -0.050 | +0.115 | +0.115 | +0.069 | +0.054 | +0.047 | +0.026 | +0.051 |
| 24 | -0.036 | +0.074 | +0.123 | -0.035 | +0.017 | +0.033 | +0.106 | -0.033 | +0.054 | +0.090 | +0.061 | -0.038 | +0.099 | +0.004 | +0.055 |

TABLE C.IV (Continued)

| S | Trials 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nonretarded 13-14 Year Olds | | | | | | | | | | | | | | |
| 25 | -0.073 | -0.000 | -0.011 | -0.197 | -0.054 | -0.062 | -0.004 | +0.017 | -0.068 | -0.074 | -0.024 | -0.054 | -0.092 | -0.024 | -0.050 |
| 26 | +0.119 | +0.046 | +0.065 | +0.114 | +0.132 | +0.137 | +0.092 | +0.074 | +0.094 | +0.125 | +0.181 | +0.128 | +0.038 | +0.142 | +0.100 |
| 27 | +0.024 | +0.018 | +0.071 | +0.029 | -0.006 | -0.017 | +0.066 | +0.021 | +0.094 | -0.009 | -0.018 | +0.003 | +0.055 | +0.092 | +0.013 |
| 28 | -0.039 | +0.047 | +0.020 | +0.084 | -0.041 | +0.034 | +0.054 | +0.101 | +0.105 | +0.062 | +0.004 | -0.028 | +0.018 | +0.027 | +0.052 |
| 29 | -0.013 | +0.026 | +0.073 | +0.074 | +0.027 | +0.188 | +0.024 | +0.073 | +0.127 | +0.129 | +0.106 | +0.115 | +0.079 | +0.129 | +0.084 |
| 30 | -0.152 | -0.050 | -0.028 | -0.024 | +0.037 | +0.086 | -0.032 | -0.042 | +0.020 | -0.040 | -0.056 | -0.085 | -0.045 | +0.014 | +0.024 |
| 31 | +0.034 | +0.113 | +0.135 | +0.072 | +0.038 | +0.121 | +0.113 | +0.093 | +0.078 | +0.094 | +0.089 | +0.087 | +0.096 | +0.089 | +0.095 |
| 32 | +0.024 | +0.022 | -0.029 | -0.068 | +0.040 | -0.016 | +0.070 | +0.038 | +0.006 | +0.006 | +0.026 | +0.074 | -0.058 | +0.010 | +0.064 |
| | Nonretarded 17-21 Year Olds | | | | | | | | | | | | | | |
| 33 | +0.070 | +0.108 | +0.100 | +0.157 | +0.148 | +0.158 | +0.084 | +0.128 | +0.135 | +0.090 | +0.130 | +0.025 | +0.035 | +0.057 | +0.040 |
| 34 | +0.051 | +0.036 | +0.049 | -0.028 | +0.096 | +0.114 | +0.035 | +0.070 | +0.048 | +0.097 | +0.037 | +0.054 | +0.042 | +0.002 | +0.109 |
| 35 | +0.022 | +0.002 | +0.044 | +0.024 | +0.006 | +0.045 | +0.034 | +0.024 | +0.073 | +0.041 | -0.013 | +0.062 | +0.069 | +0.016 | +0.043 |
| 36 | +0.022 | +0.042 | -0.008 | +0.023 | +0.043 | +0.051 | +0.021 | -0.001 | -0.029 | -0.023 | -0.043 | +0.046 | +0.033 | -0.010 | +0.008 |
| 37 | +0.033 | +0.072 | +0.058 | +0.065 | +0.100 | +0.063 | +0.038 | +0.064 | +0.054 | +0.001 | +0.034 | +0.063 | +0.046 | +0.034 | +0.067 |
| 38 | +0.075 | +0.104 | +0.076 | +0.066 | +0.045 | +0.053 | +0.101 | +0.063 | +0.092 | +0.076 | +0.079 | +0.070 | +0.085 | +0.099 | +0.098 |
| 39 | +0.116 | +0.149 | +0.098 | +0.099 | +0.104 | +0.092 | +0.018 | +0.069 | +0.082 | -0.043 | +0.060 | +0.109 | +0.066 | +0.050 | +0.027 |
| 40 | -0.011 | +0.022 | +0.001 | -0.008 | -0.036 | +0.045 | -0.077 | -0.040 | +0.020 | +0.061 | +0.017 | +0.030 | +0.070 | -0.013 | -0 044 |

TABLE C.V.

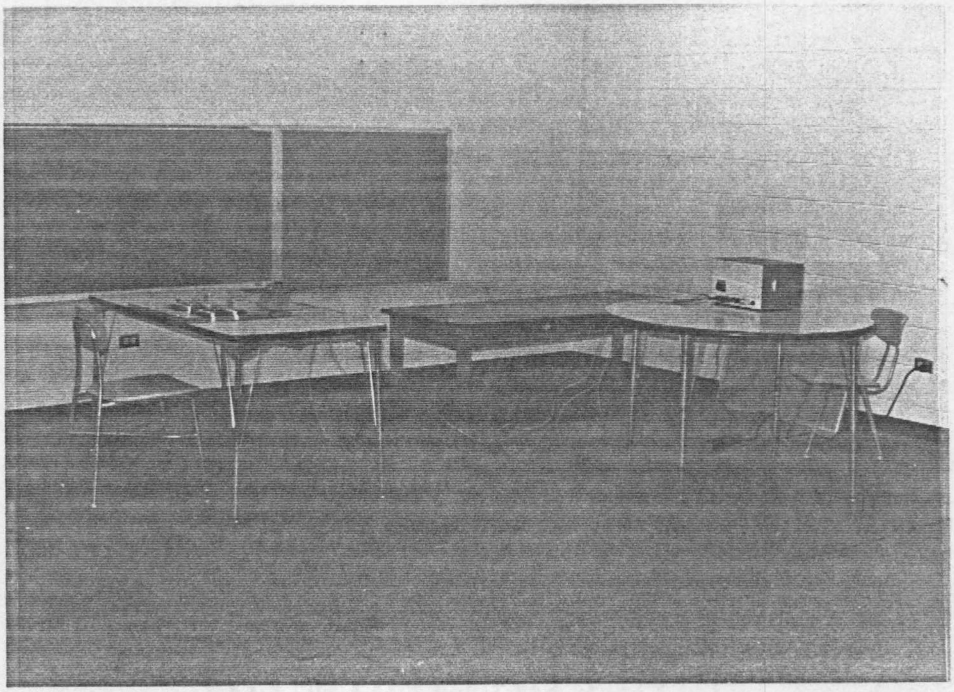
Median Reaction Time, Median Constant Error, and Variable Error Scores for All Subjects

| S | RT | VE | CE | S | RT | VE | CE |
|---|---|---|---|---|---|---|---|
| 01 | .3820 | .05187 | +.0810 | 41 | 1.1135 | .91967 | +.2975 |
| 02 | .4655 | .33627 | +.1180 | 42 | 1.8490 | .26934 | +.3390 |
| 03 | .3960 | .08271 | +.1090 | 43 | 1.0915 | .14339 | +.1790 |
| 04 | .3950 | .04583 | +.0810 | 44 | 0.3780 | .10646 | -.1180 |
| 05 | .5625 | .12498 | +.1305 | 45 | 0.5215 | .38866 | -.0495 |
| 06 | .3755 | .06400 | +.0580 | 46 | 0.5555 | .32253 | +.1630 |
| 07 | .3825 | .06409 | +.0660 | 47 | 0.6295 | .13199 | +/1790 |
| 08 | .3565 | .15530 | +.0310 | 48 | 0.5370 | .50240 | +.0335 |
| 09 | .3680 | .04493 | +.0660 | 49 | 0.7550 | .13665 | +.3085 |
| 10 | .3355 | .03859 | +.0455 | 50 | .5055 | .47315 | +.2195 |
| 11 | .3295 | .05388 | +.0385 | 51 | 0.4740 | .04572 | +.0365 |
| 12 | .4030 | .09239 | +.1210 | 52 | 0.4500 | .27621 | -.0095 |
| 13 | .3065 | .03070 | +.0330 | 53 | 0.5585 | .29085 | +.2285 |
| 14 | .2795 | .10070 | -.0015 | 54 | 0.4405 | .13693 | -.0450 |
| 15 | .3875 | .11924 | +.1085 | 55 | 0.7455 | .45763 | +.2505 |
| 16 | .3450 | .04845 | +.0510 | 56 | 0.4875 | .15499 | +.1695 |
| 17 | .4210 | .04549 | +.0945 | 57 | 0.3400 | .09831 | -.0315 |
| 18 | .3305 | .04487 | +.0665 | 58 | 1.1280 | .27154 | +.2650 |
| 19 | .3040 | .02929 | +.0585 | 59 | 0.6075 | 1.01870 | +.2035 |
| 20 | .2945 | .05990 | +.0085 | 60 | 0.3230 | .04142 | -.1840 |
| 21 | .3235 | .09788 | +.0615 | 61 | 0.5995 | .07896 | +.1875 |
| 22 | .2810 | .03417 | +.0060 | 62 | 0.4870 | .26476 | +.1750 |
| 23 | .2800 | .05655 | -.0015 | 63 | 0.3875 | .04393 | +.0415 |
| 24 | .2985 | .05194 | +.0540 | 64 | 0.4640 | .51554 | +.0715 |
| 25 | .3325 | .06187 | +.0730 | 65 | 0.3360 | .05404 | -.0025 |
| 26 | .3270 | .03791 | +.0195 | 66 | 0.3420 | .11902 | +.0550 |
| 27 | .3190 | .03829 | +.0140 | 67 | 0.2990 | .02938 | -.1295 |
| 28 | .2990 | .04261 | -.0390 | 68 | 0.3970 | .11735 | +.1640 |
| 29 | .3545 | .05190 | +.1040 | 69 | 0.3155 | .08597 | -.0260 |
| 30 | .3280 | .04495 | +.0505 | 70 | 0.3900 | .03223 | +.0985 |
| 31 | .3485 | .02653 | +.0935 | 71 | 0.3735 | .05217 | +.0965 |
| 32 | .3050 | .03768 | -.0300 | 72 | 0.4455 | .12874 | +.1885 |

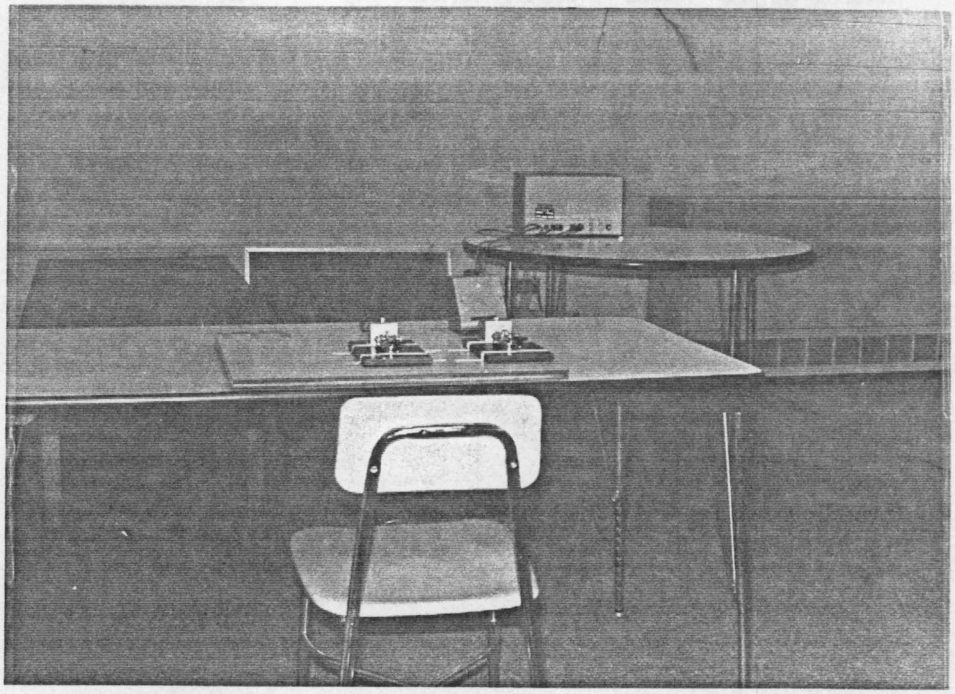
TABLE C.V. (Continued)

| S | RT | VE | CE | S | RT | VE | CE |
|---|---|---|---|---|---|---|---|
| 33 | .3215 | .02594 | +.1285 | 73 | 0.3050 | .08583 | +.0475 |
| 34 | .2835 | .03202 | +.0485 | 74 | 0.3675 | .04338 | +.1325 |
| 35 | .2510 | .02370 | +.0290 | 75 | 0.2880 | .09377 | +.0255 |
| 36 | .2775 | .02993 | +.0100 | 76 | 0.3550 | .07200 | +.0885 |
| 37 | .2975 | .02555 | +.0870 | 77 | 0.3040 | .08728 | +.0420 |
| 38 | .2865 | .01853 | +.0605 | 78 | 0.2410 | .02977 | -.0480 |
| 39 | .2915 | .05212 | +.0760 | 79 | 0.3305 | .07193 | +.0860 |
| 40 | .2475 | .03709 | +.0090 | 80 | 0.3185 | .04665 | +.0490 |

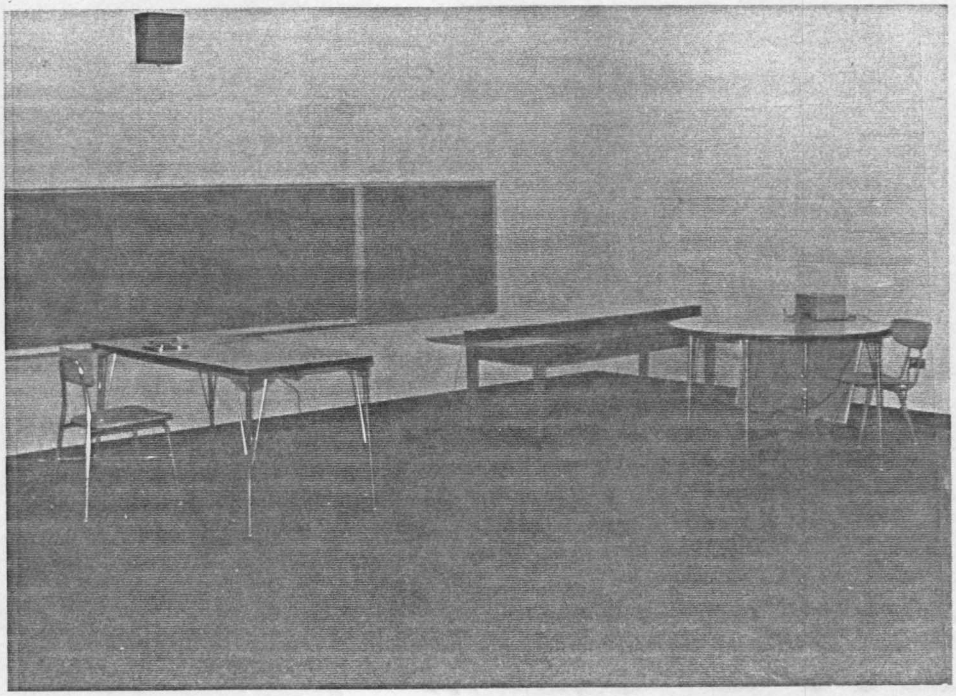
# APPENDIX D



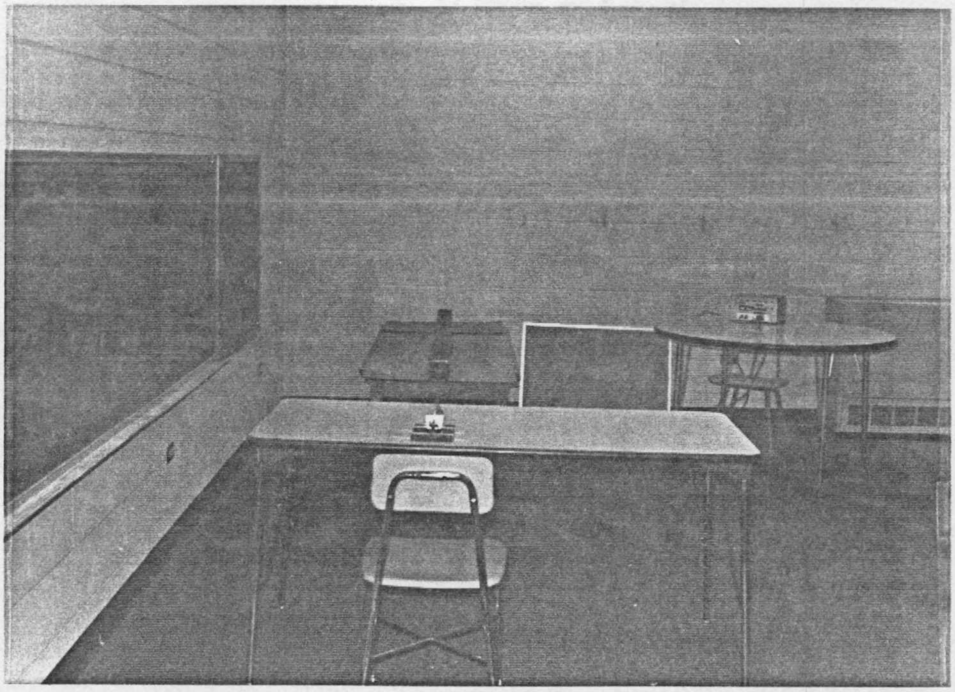
Reaction Time Task Apparatus



The Subject's View of Reaction Time Task Apparatus



Coincidence Anticipation Task Apparatus



Subject's View of Coincidence Anticipation Task Apparatus

## VITA

Margaret Ellen Wooddy was born in Ripley, Mississippi on November 1, 1951. She attended elementary and secondary schools in Texas and was graduated from O. D. Wyatt High School in Fort Worth, Texas in June 1970. The following August she entered Baylor University, and in May 1974 she received a Bachelor of Science degree in Health, Physical Education, and Recreation. In the fall of 1974 she began teaching in the Waco Independent School District of Waco, Texas.

After teaching one year in junior high school, she accepted a graduate assistantship in athletics at Baylor University and received a Master of Science degree in Physical Education in August 1975. In August of that same year she accepted a teaching and coaching position at Baylor University. In 1980 she was granted a leave of absence from Baylor University to pursue a doctoral degree, and entered The University of Tennessee, Knoxville, in the fall of 1980.

She received the Doctor of Philosophy degree with a major in Education in August 1983, and returned to Baylor University as assistant professor to teach in the physical education department.