

The Young Child's Perception of Duration

by

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This thesis is dedicated to the memory
of my former thesis advisor

Dr. M. Sam Rabinovitch

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ABSTRACT

The young child's subjective experience of duration was explored within a developmental context. Extraneous factors which influence children's time judgments were examined. The method of cross-modality matching was used to estimate tones of short duration and familiar school routines. Cognitive and behavioral skills were investigated as predictors of the children's precision on both duration tasks. Major results were as follows: (1) Children between 5 and 10 years were able to estimate duration of pure tones ranging from 2 to 25 seconds without explicit feedback. Younger children were not as accurate or as consistent as young adults; however, they performed better than elderly subjects and improved in consistency with age. (2) Children's duration estimates of tone sequences were influenced by stimulus contextual variables of speed, familiarity and organization. Familiarity and organization affected time judgments given by children in the same manner as young adults. (3) Kindergarteners and first graders had greater difficulty estimating duration of routines than of tones. Extraneous procedural variables interfered with their temporal estimates whereas task pleasantness and task difficulty did not. (4) Memory capacity and temporal behavioral skills were more important determinants of children's precision in estimating routines than tones. Results were discussed primarily in terms of Ornstein's (1969) cognitive information processing model of duration experience. These findings contribute to a better understanding of the perceptual and cognitive mechanisms underlying the development of temporal estimation ability.

The Young Child's Perception of Duration

Psychology Ph.D.

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La Perception De La Durée Chez Le Jeune Enfant

L'expérience subjective de la durée a été explorée chez le jeune enfant à l'intérieur d'un contexte développemental. Les facteurs externes influençant l'évaluation du temps chez l'enfant ont été étudiés. Une méthode d'assortissement de stimuli provenant de différentes modalités sensorielles a été utilisée pour l'estimation de sons de courte durée et des routines d'école familières. Les habiletés cognitives et comportementales de ces enfants ont été investiguées, en tant que facteurs prédicteurs de leur précision à accomplir ces tâches. Les résultats majeurs sont les suivants: (1) Les enfants de 5 à 10 ans ont été capables d'estimer la durée de tons purs allant de 2 à 25 secondes sans feed-back explicite. Les enfants de plus jeune âge se sont montrés moins exacts ou consistants que les jeunes adultes; cependant leur performance était supérieure à celle des vieillards et devint plus consistante avec l'âge. (2) L'estimation de la durée de séquences de sons par les enfants fût affectée par les stimuli contextuels suivants: les variables de vitesse, familiarité et organization. La familiarité et l'organization des stimuli ont influencé les jeunes enfants de la même façon que les jeunes adultes dans leur évaluation du temps. (3) Les enfants du niveau de la maternelle et de la première année ont eû plus de difficulté à estimer la durée des routines scolaires que celle des sons. Les variables expérimentales externes ont interféré avec leurs estimés, mais non la difficulté ou l'agrément de la tâche. (4) Les capacités mnésiques et comportementales temporelles des enfants se sont avérées être des déterminants plus puissants dans leurs estimations de la durée des routines que dans celles des sons. Ces résultats sont discutés principalement dans le contexte du modèle cognitif des processus d'information d'Ornstein (1969) ayant trait à l'expérience de la durée. Ces conclusions contribuent à approfondir notre connaissance des mécanismes perceptuels et cognitifs qui sous-tendent le développement de la capacité d'estimer le temps.

TABLE OF CONTENTS

	Page
List of Tables	i
List of Figures	iv
List of Appendices	v
INTRODUCTION	1
Types of Temporal Knowledge	7
Measurement of Subjective Duration	10
Adult Models of Time Perception	21
Child Models of Time Perception	31
General Statement of Problem	57
EXPERIMENT 1	59
EXPERIMENT 1A: Age Differences in Duration Estimates of Tones	70
Method	70
Results	77
EXPERIMENT 1B: Duration Estimation as a Function of Stimulus Contextual Variables	90
Method	90
Results	92
Discussion	95
EXPERIMENT 2	105
EXPERIMENT 2A: Children's Duration Estimates of Tones	117
Method	117

	Page
Results	120
EXPERIMENT 2B: Children's Duration Estimates and Subjective Ratings of Rou- tines	133
Method	133
Results	138
EXPERIMENT 2C: Cognitive and Behavioral Measures as Predictors of Children's "Pre- cision" on Duration Tasks	163
Method	163
Results	177
GENERAL DISCUSSION	196
REFERENCES	215
APPENDICES	230

LIST OF TABLES

	Page
1. Group Regression Analyses for Duration Judgments of Tones by Four Age Groups	78
2. Best Fitting Model Derived from Group Regression Analyses for Duration Judgments of Tones by Four Age Groups	79
3. Two-Way Analysis of Variance of the Effects of Tone Length on Duration Judgments by Four Age Groups	82
4. One-Way Analysis of Variance of Standard Error Scores for Duration Judgments of Tones by Four Age Groups	87
5. One-Way Analysis of Variance of Slopes for Duration Judgments of Tones by Four Age Groups	87
6. Three-Way Analysis of Variance of the Effects of Age Group, Stimulus Condition and Stimulus Rate on Duration Judgments of Tone Sequences	93
7. Tukey Test Comparing Duration Judgments of Different Stimulus Rates for Grade 1 Children	94
8. Tukey Test Comparing Duration Judgments of Different Stimulus Rates for Grade 4 Children	94
9. Group Regression Analyses for Duration Judgments of Tones by Kindergarten and Grade 1 Children	121
10. Best Fitting Regression Model Derived from Group Regression Analyses for Duration Judgments of Tones by Kindergarten and Grade 1 Children	122
11. Two-Way Analysis of Variance of the Effects of Tone Length and Block on Duration Judgments by Kindergarten Children	125
12. Three-Way Analysis of Variance of the Effects of Tone Length, Block and Classroom Group on Duration Judgments by Grade 1 Children	127
13. One-Way Analysis of Variance of the Effects of Age Group on Standard Error Scores of Duration Judgments of Tones	132

	Page
14. One-Way Analysis of Variance of the Effects of Age Group on Slopes of Duration Judgments of Tones	132
15. Group Regression Analysis for Duration Judgments of Routines by Kindergarten Children (all predictors included)	139
16. Group Regression Analysis for Duration Judgments of Routines by Kindergarten Children (fun predictor deleted)	139
17. Best Fitting Model Derived from Group Regression Analyses for Duration Judgments of Routines by Kindergarten and Grade 1 Children	141
18. Three-Way Analysis of Variance of the Effects of Block, Duration Category and Activity Type on Duration Judgments by Kindergarten Children	143
19. Newman-Keuls Tests Comparing Duration Judgments of Routines According to Duration Category for Kindergarten Children	145
20. Group Regression Analysis for Duration Judgments of Routines by Grade 1 Children (all predictors included)	149
21. Group Regression Analysis for Duration Judgments of Routines by Grade 1 Children (fun predictor deleted)	149
22. Three-Way Analysis of Variance of the Effects of Block, Classroom Group and Activity Type on Duration Judgments by Grade 1 Children	152
23. Scheffé Tests Comparing Duration Judgments of Routines According to Duration Category for Grade 1 Children	154
24. One-Way Analysis of Variance of the Effect of Age Group on Standard Error Scores of Duration Judgments of Routines	159
25. One-Way Analysis of Variance of the Effects of Age Group on Slopes of Duration Judgments of Routines	159
26. Group Regression Analyses for Duration Judgments of Routines by Kindergarten and Grade 1 Children (forced order entry for Time, Last R and Trial only)	161

	Page
27. Correlation Matrix of Test Battery Measures and Measures of Precision for Kindergarten Children	180
28. Correlation Matrix of Test Battery Measures and Measures of Precision for Grade 1 Children	181
29. Loadings on Four Varimax Factors for Fifteen Variables Taken from Kindergarten Test Battery	185
30. Loadings on Five Varimax Factors for Fifteen Variables Taken from Grade 1 Test Battery	188
31. Group Regression Analysis for Kindergarten Children: Factors as Predictors of SEE of Tone Duration Judgments	191
32. Group Regression Analysis for Kindergarten Children: Factors as Predictors of ACC of Tone Duration Judgments	191
33. Group Regression Analysis for Kindergarten Children: Factors as Predictors of RSEE for Duration Judgments of Routines	192
34. Group Regression Analysis for Kindergarten Children: Factors as Predictors of RACC for Duration Judgments of Routines	192
35. Group Regression Analysis for Grade 1 Children: Factors as Predictors of SEE of Tone Duration Judgments	194
36. Group Regression Analysis for Grade 1 Children: Factors as Predictors of ACC of Tone Duration Judgments	194
37. Group Regression Analysis for Grade 1 Children: Factors as Predictors of RSEE for Duration Judgments of Routines	195
38. Group Regression Analysis for Grade 1 Children: Factors as Predictors of RACC for Duration Judgments of Routines	195

LIST OF FIGURES

	Page
1. Time estimation apparatus	72
2. Mean judgments of duration of variable tones for four age groups	84
3. Individual standard error scores plotted against individual slopes for duration judgments of tones by four age groups	89
4. Mean judgments of duration of variable tones for kindergarten and grade 1 children	129
5. Mean judgments of duration of routines collapsed over activity type for kindergarten children	146
6. Mean judgments of duration of individual activities for kindergarten children	148
7. Mean judgments of duration of routines collapsed over activity type for grade 1 children	155
8. Mean judgments of duration of individual activities for grade 1 children	157

LIST OF APPENDICES

	Page
A. Summary Tables of Newman-Keuls Test Comparing Duration Judgments of Variable Tones for Four Age Groups in Experiment 1A	230
B. Summary Tables of Best Fitting Regression Model for Each Individual Subject for Duration Judgments of Tones in Experiment 1A	232
C. Summary Table of Newman-Keuls Tests Comparing Standard Error Scores of Duration Judgments of Tones Across Four Age Groups in Experiment 1A	236
D. Summary Table of Newman-Keuls Tests Comparing Slopes of Duration Judgments of Tones Across Four Age Groups in Experiment 1A	237
E. Follow-Up Questionnaire Given to Adults in Experiment 1	238
F. Order of Presentation of Randomized Tones for "Unfamiliar" Condition in Experiment 1B	239
G. Summary Tables of Newman-Keuls Tests Comparing Duration Judgments of Variable Tones for Kindergarten and Grade 1 Children in Experiment 2A	240
H. Summary Tables of Best Fitting Regression Model for Each Individual Subject for Duration Judgments of Tones in Experiment 2A	242
I. Samples of Picture Cards of Familiar School Routines Used in Experiment 2B	244
J. Summary Tables of Best Fitting Regression Model for Each Individual Subject for Duration Judgments of Routines in Experiment 2B	245
K. Time Questionnaire Given to Elementary School Teachers as Part of Pilot Study in Experiment 2C	247
L. Numerical Memory Subtest from McCarthy Scales of Children's Abilities Used in Experiment 2C	261

	Page
M. Test of Memory Span for Unrelated Words Used in Experiment 2C	262
N. Oral Commissions Subtest from The Detroit Tests of Learning Aptitude Used in Experiment 2C	263
O. Two Samples of Sequence Used in Test of Temporal Sequencing Ability in Experiment 2C	264

INTRODUCTION

Throughout the history of man, the experience of time has been an intriguing subject of theoretical speculation among scholars from a variety of disciplines. Philosophy and religion, music, history, the life sciences, and the physical sciences have each offered constructs to better understand this seemingly intangible phenomenon.

Early philosophers concerned themselves primarily with the genesis of time; yet many of the issues which puzzled them are still of concern. Most western philosophers agree that our idea of time comes from change (Fraïsse, 1963), but heated debates have ensued between rationalist and empiricist schools regarding its nature and origin. Is the experience of change derived from changes in sensations or changes in our thoughts? Is time merely a construction of the mind or does it have some objective permanence outside of ourselves? For Hume and Condillac, extreme empiricists, time did not exist outside the subjective realm of the senses. In contrast, Descartes argued that temporal experience was the inevitable product of the succession of thoughts and ideas. Kant characterized time as a form of intuition "built into" the mind such that men are predisposed to view their world temporally. He did, however, provide time with an objective status as well, claiming that time is "a property of the instrument by which we view things" (Benjamin, 1966, p. 23), and therefore must be referenced in the

external world of objects.

As is apparent even from this very brief synopsis, the debate has become very much a battle of words since philosophical terms seem vague and contradictory and solutions too often achieved through analogy and metaphor. Psychologists have attacked the problem of time more objectively and have made a very necessary contribution to the debate, namely empirical data. Avoiding some of the dangers of endless theoretical argument, psychologists have concerned themselves less with the notion of time and have focussed instead on our awareness of its two fundamental aspects: succession and duration.

With the beginning of experimental psychology in the middle 1800's, time perception was one of the first phenomena to be studied. An entirely new approach to the problem of time emerged under the influence of psychophysics. Within the confines of the laboratory, investigators studied the accuracy with which we perceive time and attempted to tackle such problems as: Does Weber's law apply to time? What is the minimum perceptible duration between two events? What influence do the contents of temporal intervals exert on perceived duration? (Adam, 1971; Fraisse, 1963). Predispositional factors in the subject were ignored. Instead stimulus factors, rigorously controlled and manipulated, were related to changes in temporal judgment and the relationship converted to mathematical form (Doob, 1971).

In contrast, proponents of the introspectionist movement often tried to determine how their subjects were able to make accurate time judgments. Using well-developed systematized techniques, highly trained observers attempted to analyze the contents of personal consciousness and to compare the mental images of time experience with those of their colleagues. Unfortunately, there was considerable lack of agreement, and most introspectionists could not substantiate their judgments. The experimentalists' technique provided a much more coherent and fertile method of attack.

With the advent of behaviorism, however, not only did psychophysical research diminish rapidly, but much of the research on time became scattered and forgotten. "Mentalistic" approaches to the study of time were considered unscientific, and psychologists began to deal with time in the purely objective context of examining how man's behavior is influenced by temporal factors (Ornstein, 1969). Between 1890 and 1950, one witnessed fragmentary research attempts (e.g. Harton, 1939; Hoagland, 1933; Gardner, 1935) and very little effort to integrate findings into any solid theoretical framework (Whitrow, 1972). Investigators seemed at a loss as to how to approach the subject matter given the restrictions of an objectively oriented discipline. Even in contemporary times, only a few researchers are committed to pursuing methodical investigations in this area. What seems to make research on this topic exceedingly difficult is that time, in contrast to

our other senses, has no organ of perception (such as the eye) for study by objective means (Ornstein, 1969).

Over the past two decades, however, renewed interest in the study of time is evident. Several recent volumes offering substantive reviews (e.g. Doob, 1971; Fraser, 1966; Whitrow, 1972) and new systematic psychological experimentation (e.g. Goldstone and Goldfarb, 1966; Ornstein, 1969; Vroom, 1970) attest to this growth in appeal. Fraisse may have been largely responsible for stimulating these efforts when in 1963, his book entitled The Psychology of Time, offered the first comprehensive survey of the time literature in psychology. But perhaps more important still, recent advancements in cognitive and developmental psychology, psychophysics and neurophysiology have allowed for a more sophisticated return to the examination of mental and physiological processes involved in the perception of time.

Contemporary research on time perception has increased but often in many different directions. In contrast to the systematic investigations carried out by early psychophysicists, the present trend has been towards a more molar approach. Temporal experience has been related to a host of cognitive, social, physiological and personality variables (Doob, 1971; Wallace and Rabin, 1960). But while it has been noted that the perception of time is related to man's intelligence (Terman, 1916), personality (e.g. Buchwald and Blatt, 1974; Eysenck, 1959; Lynn, 1961) and social status (e.g.

Goldstone, Boardman, Lhamon, Fason and Jernigan, 1963; Le Shan, 1952), relatively little is known about the perceptual process itself. It is now well-documented that time perception is one of the first mental functions to be impaired by psychopathology (e.g. Dilling and Rabin, 1967; Israeli, 1936; Meerloo, 1966; Lhamon, Goldstone and Goldfarb, 1965) and metabolic dysfunction (e.g. Hoagland, 1933; Luce, 1971). Nevertheless, psychologists have as yet been unable to determine the sensory and cognitive processes responsible for temporal behavior.

The present study examines the perception of time within a developmental context and focusses on what has been a largely neglected subject: the young child's subjective experience of duration. Early philosophers viewed the time sense as genetic in origin. Presently, however, there is ample evidence to support the developmental nature of this capacity (Wallace and Rabin, 1960). So far, however, there is very little empirical data documenting age group differences in the accuracy and consistency with which duration judgments are made. Furthermore, few formal theories have been proposed to account for the maturation of temporal estimation ability. Instead, theoretical and research efforts in the child area have been devoted to acquiring a better understanding of the ways in which the representation of the perceptual process develops; that is, how children learn about temporal units and concepts. With the rapid growth and popularity of psycholinguistics, much has been written in the last decade on the use and understanding of temporal

language (e.g. Bever, 1970; Clark, 1973; Friedman and Seely, 1976), but the perception of time has been neglected. While progress concerning the child's conception of time is not to be under-valued, it would seem that an adequate understanding of the development of temporal conceptual behavior requires the study of the perceptual process as well.

Two fairly comprehensive theories have been advanced in the adult literature to account for perception of duration. Unfortunately there has been little attempt to apply these models to time perception in children. One stresses the role of sensory and biological processes; the other emphasizes the processes of cognition and memory. While these two approaches are not mutually exclusive, they have often been treated as such by their strongest advocates. Research to date has demonstrated that a number of variables, both objective and subjective, may influence the perception of time and it is highly likely that both cognitive and physiological variables are involved. The question still facing experimentalists is: Which variables are most pertinent, under these circumstances, with this subject population? The child literature on the other hand, is still struggling with the conceptual framework provided by Piaget (1969).

It has been exceedingly difficult to study the processes which underlie subjective temporal experience of adults. By adulthood, time perception has become a highly learned skill influenced by knowledge of clocktime and numerous other socio-

cultural factors (Doob, 1971). Thus our understanding of time perception may be enhanced by trying to apply these adult models to the young child's experience of duration. In this investigation, children's judgments of duration were examined primarily within the context of cognitive information processing theory (Ornstein, 1969). The implications of both frameworks, however, were taken into account.

The scientific study of time perception might be approached from a variety of vantage points. The present series of studies explored the perceptual process using rigorous procedures provided by the psychophysical tradition but rarely used in developmental psychology. The pioneers of time perception research became disillusioned because of inadequate theories, ineffective methods and difficulties defining the subject matter. Some of these limitations have been overcome, others remain to be mastered. Prior to a discussion of existing theoretical frameworks and experimental findings, some of the more general conceptual and methodological issues will be considered.

Types of Temporal Knowledge

A necessary first step toward obtaining a coherent picture of time perception is to clarify the concept and its various dimensions. There are many forms of time. One of

the stumbling blocks in psychological investigations has been the confusion between three modes of time: experiential time, biological time and clocktime. The concept of experiential or subjective time refers to the individual's personal experience of the passage of time. Whether or not a duration is felt to be long or short may be quite distinct from that indicated by the clock (i.e. objective or external time). Similarly, biological time, that is the rhythmic processes observed in animal and human life (e.g. heart rate, respiratory rate), may or may not reflect temporal experience.

Experiments in psychology have often been performed to determine how accurately "real" time is perceived. One of the reasons why young children were excluded from many of these studies was because most methodologies required the subject to have a sophisticated knowledge of clocktime. In the present series of studies a somewhat novel procedure was introduced so that the young child's experience of duration could be compared with that of adults.

For a better understanding of time perception, it is also important to clarify the different dimensions of time experience. Ornstein (1969) has classified temporal experience into four dimensions: the present or short-term time (3 to 4 sec), duration having some permanence (intervals above 10 sec), temporal perspective (i.e. the experience of future time) and the experience of simultaneity and succession. Several category schemas have been proposed (e.g. Bateman, 1968; Cottle,

1969; Fraisse, 1963; Loehlin, 1959; Woodrow, 1951) but authors have failed to agree both on the number of categories that should be used and on the quantitative units that define these different dimensions. There seem to be as many descriptions of time as there are experiences of it. It is essential, however, that researchers come to some consensus of opinion regarding the quantification and classification of temporal experience. Recent research efforts (e.g. Vroon, 1970) suggest that different mechanisms underlie different modes of time perception and contradictory results may be a direct result of failure to appreciate this distinction. Thus, before a theory of time perception can be clearly articulated the classification issue must be further examined.

Ornstein's (1969) division between short-term time and duration is based on a memory model: the present as short-term storage and duration as long-term storage. Several other authors also report evidence that long intervals are evaluated by different cognitive processes than are shorter ones (e.g. Avant and Lyman, 1975; Cohen, 1966; Loehlin, 1959; Vroon, 1970). In contrast, it may well be that sensory processes play a greater role than cognition in our perception of simultaneity and succession (Adam, 1971). The developmental literature which documents the slow, predictable growth of temporal skills and concepts (e.g. Ames, 1946; Bateman, 1968; Fraisse, 1963) supports the notion that different sensory and cognitive processes may be involved to a greater or

lesser extent depending on the temporal phenomenon under study.

Most psychophysical studies of time perception in children have been concerned with the estimation of short time intervals of not more than a few seconds (e.g. Goldstone and Goldfarb, 1966; Smythe and Goldstone, 1957). Short durations and simple time stimuli (e.g. tones) have been used in order to minimize problems of attention and other interfering variables. Consequently, very little is known about the young child's experience of longer time intervals involving more relevant stimuli such as familiar activities. In the present series of studies, children were given the task of estimating both short (tones) and long (activities) durations. In addition, cognitive and behavioral skills that enable children to make temporal judgments were examined. The feasibility of generalizing results from one temporal domain to the other was given careful consideration.

Measurement of Subjective Duration

In an attempt to identify the cues or events used by subjects to mark the passage of time, various methodologies have been employed. Those most commonly used are of four types:

(1) verbal estimation in which the experimenter presents an interval (standard) and the subject is asked to give a verbal estimate in seconds or minutes, (2) production (operative

estimation) in which the subject is asked to delimit operatively an interval verbally stated by the experimenter, (3) reproduction in which the experimenter presents an interval (standard) by means of some operation and the subject is asked to reproduce operatively an interval of the same duration, (4) paired comparison in which two intervals are presented by the experimenter and the subject is asked to judge which is longer. Within the latter three categories, various psychophysical scaling techniques have been used to obtain subjective estimates (Gescheider, 1976). For instance, the subject might be asked to indicate the duration of a stimulus by using a series of numbers (e.g. 5-point scale), adjectives (e.g. short, medium, long) or by producing the same stimulus magnitude in another modality (e.g. adjusting the intensity of light to correspond to the duration of a tone).

The utilization of different methodologies has presented a number of problems for experimentalists. Of most serious concern has been the finding that different methods yield different results and consequently may be measuring different underlying functions (e.g. Clausen, 1950; Bindra and Waksberg, 1956; Carlson and Feinberg, 1970; Doob, 1971). In a well-known study by Clausen (1950) wherein the first three methods were compared, verbal estimates given by schizophrenic subjects were inversely related to estimates obtained from these same subjects using the method of production. Subjects

were able to be most accurate when intervals were reproduced but these judgments were also less reliable. Estimates were least accurate (overestimated) under conditions of verbal estimation. This latter result has more recently been replicated using a normative sample (Goldfarb and Goldstone, 1963). The inverse relationship between verbal estimation and production has also been documented in normal subjects (e.g. Bindra and Waksberg, 1956; Carlson and Feinberg, 1968). Data such as these raise the question of how to compare results obtained using different methods. Presently, there is ample evidence that the different methodologies are differentially affected by procedural and stimulus factors (Bindra and Waksberg, 1956) but a good deal more research needs to be done to clarify these differences.

A further confusion has been one of terminology, in particular, the inappropriate use of the terms under- and over-estimation (Bindra and Waksberg, 1956; Woodrow, 1951). Choice of terms must depend on whether the stimulus or response is used as the standard (or reference stimulus) and also whether or not some internal mechanism responsible for temporal judgments is being postulated. Bindra and Waksberg (1956) have noted that when the method of reproduction is used, the subject's subjective scale category is not as easily discerned because he must first categorize the stimulus and then use this category to operatively produce the interval. It should be noted, however, that regardless of the method used, the

"psychological magnitude" of the stimulus cannot be directly observed but is only inferred from whatever responses the subject makes (Eiser and Stroebe, 1972). Thus, one can speak about the relationship between duration judgments and the actual lapse of time but statements regarding the perceptual mechanisms underlying the judgment must remain tentative.

Of concern to the present investigator was the as yet unanswered question of what method is most suitable for use with young children. Most studies concerning temporal duration have relied on clocktime judgments given by subjects. Sophisticated subjective scaling techniques have only recently been explored and are much more commonly used in investigations of other perceptual continua such as brightness, loudness, and heaviness (Stevens, 1971; Stevens and Gallanter, 1957). The method of reproduction, in which the subject presses a button to reproduce an interval, is an adequate alternative for estimation of short durations. It would be unsuitable, however, for measuring longer intervals due to the complex interactive effects of memory and attention.

The method chosen for the present series of studies was one of recent innovation and has been referred to as "cross-modality matching" (Stevens, 1971). Here the subject is required to match stimulus values of one modality with those of another modality such that the sensory magnitudes are the same. In a study by Bond and Stevens (1969), adults and 5-year old children were equally able to match the intensity of

light with the loudness of a tone. It was suggested that the method of cross-modality matching is a more direct measure of sensory process and less affected by mediating thoughts concerning measurement scales. For purposes of studying duration, length of line was chosen as the alternative modality to be equated with duration. The choice of length was based on observations by several authors (e.g. Fraisse, 1963; Piaget, 1966, 1969) that for the young child, time and space are intimately connected. In fact, Piaget has demonstrated that preoperational children completely fail to dissociate temporal order and interval from spatial order and interval (Flavell, 1963).

Contemporary research in psychophysics suggests that Stevens' Power Law best describes how dimensions of physical stimuli and our impressions of them are related. Based on a multitude of experiments from a dozen perceptual continua (Stevens and Gallanter, 1957; Stevens, 1962, 1971), Stevens concluded that magnitude estimation for a variety of sensory dimensions increases in proportion to the stimulus intensity raised to a power. The law stipulates that equal stimulus ratios produce equal sensation ratios; the size of the power exponent is said to be dependent upon the sensory modality and a variety of factors related to stimulus conditions.

Studies exploring the application of this formula to temporal duration have so far used mainly adults as subjects. Results have indicated that a power function with an exponent

of approximately 1.0 best describes the relationship between apparent auditory duration and actual time (Stevens and Gallanter, 1957; Ross and Katchmar, 1951; Chatterjea, 1964; Gescheider, 1967; Michon, 1967). Judgments of line length have also been demonstrated to fit a simple power function with a corresponding exponent of 1.1 (Stevens and Gallanter, 1957; Ward, 1974). The astonishing consistency of the temporal estimation finding was attested to by an extensive survey carried out by Eisler (1976) in which exponents for subjective duration were compiled from over one hundred studies spanning 1868 to 1975. While several factors were shown to influence the size of the exponent (e.g. method of estimation, practice, sensory modality, drugs) there was comparatively small variation across studies indicating remarkable stability in data for time perception.

But the validity of Stevens' power function can only be assumed over a limited range (Stevens, 1962) and the above computations are taken mostly from group data. Yet a high degree of individual variation in temporal judgments is common to almost all studies on time perception (Woodrow, 1933). Doob (1971), in his review of the psychophysical literature, made the following statement: "In virtually every psychophysical investigation based upon more than a handful of subjects, the fact of interpersonal variability looms large" (p. 105). He has claimed that many of the contradictions in findings are due to predispositional factors (e.g. subject's

attention span, fatigue, attitude toward sources of stimulation) which cannot always be excluded and may therefore have marked effects on outcome.

It is of particular importance that individual differences be examined when young children are being tested and developmental considerations are being explored. Between the ages of 5 and 7 years, various cognitive skills are just beginning to develop (Piaget, 1966) and for many, their knowledge of clocktime and duration is in a state of transition. Thus one would expect individual differences to be maximized when studying young children. Only one experiment was found in which Stevens' power law was applied to duration judgments and individual findings closely scrutinized. Richards (1964) examined the responses of two adult and two child subjects using the method of reproduction. His analyses indicated that time estimates could not be described by a single monotonic function of actual time. Rather a great deal of inconsistency was found in the judgments made by each individual which could at best be described in terms of several functions.

In the past few decades, psychophysicists have made great strides in developing new methods and scaling techniques (Gescheider, 1976; Stevens and Gallanter, 1957). A number of procedural variables have also been shown to influence psychophysical judgments. Woodrow (1951) offers a thorough review of time perception studies that deal with these procedural parameters. Those directly pertinent to this investigation include:

consequences of using a repeated measures design, use of a standard or stimulus range and subject's awareness of the purpose of the experiment.

In the series of studies which follow, a repeated measures design was used in which each subject was tested with two trials under each of the conditions. Most time perception studies have used repeated measures because by so doing, the stability of judgments is increased (Woodrow, 1951). Carlson and Feinberg (1970), in addition to numerous other writers (e.g. Gescheider, 1976; Richards, 1964; Stevens and Gallanter, 1957; Woodrow, 1951) have demonstrated that subjects' duration estimates are not constant from trial to trial and thus highly susceptible to variable error. On the other hand, progressive errors often occur as a consequence of continued experience or successive trials on time duration tasks. Practice effects may result in that the subject begins to make more accurate judgments with each additional trial. In contrast, if the subject becomes bored or fatigued, deterioration may result.

Falk and Bindra (1954) have noted serial position effects in that when several intervals of the same duration are produced and no feedback provided, second and subsequent intervals are likely to be increasingly overestimated. In addition, when the duration of two stimuli are compared, time-order effects have been observed. In judging two stimuli of identical duration, the latter is often perceived to be longer

than the former. This "negative time-order" effect has been explained using stimulus trace theory (Woodworth and Schlosberg, 1954). Progressive errors may be minimized by taking such precautions as counterbalancing and randomization of trials, however, these effects are likely to occur in any time estimation task employing repeated measures. Thus trial effects should be directly examined in statistical analyses.

Time-order and series effects are of direct concern when considering whether or not to ask the subject for an absolute judgment of time or to present him with some standard or stimulus range for comparison. In the studies which follow, the latter two techniques were used in an attempt to discern which would be most appropriate for use with young children. Currently, little is known about the differential effects or relative merits of these manipulations when the method of cross-modality matching is employed (Gescheider, 1976). However, even when the experimenter does not provide a standard for comparison, the subject may use an "internal" standard, either consciously or unconsciously, against which to compare his judgments. As pointed out by Woodrow (1951): "This standard is largely a function of recent temporal experiences, or of a composite trace left by them" (p. 1229). The phenomenon is of interest here because subjects, and in particular young children, may not take into account information about the standard or stimulus range despite the fact that such information has been made available.

In this investigation, the stimulus range was defined using a single anchor, as well as "end anchoring" (Eiser and Stroebe, 1972). Anchors were used such that the duration of stimuli lying just outside the series presented were identified for the top and bottom ends of the scale. Various experimenters have demonstrated that by introducing such anchors and varying the context, judgments may be greatly altered. In reference to duration, Postman and Miller (1945) demonstrated anchor effects for auditory durations of very brief intervals. Goldstone, Boardman and Lhamon (1959) confirmed their findings that short anchors tend to pull judgments down towards the lower end of the scale and the long anchors result in the entire scale shifting upwards. Thus, the subjective scale is highly flexible and time judgments may be more or less discriminant depending on the scaling technique employed.

When the effects of serial position have been explored using psychophysical judgments of other stimulus dimensions such as loudness, assimilation and contrast have been noted (e.g. Holland and Lockhead, 1968; Ward and Lockhead, 1970, 1971). In most absolute judgment situations where feedback was provided, the present response has been found to be closer to the value of the immediately previous stimulus or response (assimilation) and further from values of responses further back in the sequence (contrast). Of interest are results when no feedback was provided or when the subject guessed the

magnitude of the next stimulus. Such conditions may parallel a situation wherein a standard is provided but not used. According to Ward and Lockhead (1971), under conditions of uncertainty, assimilation extended to stimuli further back in the series and the magnitude of assimilation grew as performance deteriorated. It would seem that subjects will tend to rely on their previous response as if it were a standard in a comparative judgment task when they have no other information to rely on. In this investigation, the possible effects of assimilation and contrast were directly examined.

A last procedural concern of time estimation studies is whether or not the subject should be informed as to the purpose of the experiment. Ornstein (1969) has pointed out that when subjects are aware of the purpose of a time estimation experiment, it is highly likely that if permitted to do so, they will use conscious strategies (e.g. counting, humming, tapping, monitoring heart or pulse rate) to increase the accuracy of their time judgments. Consequently, the experimenter may learn more about the subject's sophistication in using strategies than about his ability to estimate durations of events in more natural situations. In the experiments which follow, because young children were used and a repeated measures design employed, subjects were informed as to the purpose of the studies. The instructions given, however, severely discouraged the use of any conscious strategies.

In summary, methodologies frequently used in time

estimation studies and a number of procedural variables affecting time judgments have been reviewed. Due to the dearth of empirical research efforts in the child area, suitable methods and experimental manipulations have yet to be systematically explored. The present series of studies attempted to contribute a better understanding of methods most appropriate for use with young children by introducing a newly adopted psychophysical technique, cross-modality matching.

Adult Models of Time Perception

The adult literature offers two distinct theoretical frameworks to account for the perception of duration: a sensory process model and a cognitive information processing approach. In this investigation, the emphasis was on the latter.

Sensory Process Approach

Proponents of the sensory process approach presuppose external time stimuli existing independently of ourselves which are perceived accurately or not by an "organ" of sensation. That is, according to this view, some internal time base converts external time into internal signals. The presence of biological rhythms in man is now well-documented (Cloudsley-Thompson, 1966; Luce, 1971); however, whether or

not any one or combination of these repetitive physiological processes act as an internal time keeper remains an empirical issue.

Sensory theorists have searched for a "time base" which could be identified either with a particular periodicity or with a particular biological process, termed an "internal clock" or chronometer. Two basic units have been postulated as periodic time bases: the "indifference interval", defined as that interval of time judged most accurately (estimated at approximately 0.7 sec) and the "perceptual moment" (0.1 sec) which refers to that interval which just permits us to distinguish between repeated stimuli. Attempts have been made to connect both periodicities with some physiological process such as heartrate, gait tempo or alpha rhythm but without success (Ornstein, 1969). First, the high degree of inter-subject variability in judgments and differential effects of stimulus modality employed have made it impossible for investigators to agree on the quantitative values which should be attached to these units (Woodrow, 1951). Secondly, the few instances of positive correlational data have been insufficient as evidence for a direct link to a time base.

An overwhelming number of physiological mechanisms (biological, neurological and chemical) have been investigated as possible clocks or pacemakers. Adam (1971) offers a thorough review of these investigations and only the most pertinent of those studies need be considered here.

Body temperature was one of the first processes to be investigated. Hoagland (1933) observed an increase in his wife's tapping rate when under the influence of a fever. Similarly, Pfaff (1968) in correlating normal temperature variations with temporal judgments found that higher temperatures were related to faster productions and longer estimations. Both authors speculated that increases in body temperature reflected increases in metabolic rate resulting in overestimation of clocktime intervals. Other studies, however, are not wholly in accordance with their findings (e.g. Adam, Rosner, Hosick and Clark, 1971; Gardner, 1935; Lockhart, 1967). The possibility that heart rate, blood pressure or respiratory rate might serve as chronometers was investigated by Schaeffer and Gilliland (1938). No relationships were found between any of these variables and time estimation. Similarly, convincing evidence for the role of gait tempo (e.g. Newman, 1972) and alpha rhythm (e.g. Legg, 1968) as underlying mechanisms for time perception has been lacking.

Not all the research evidence, however, is so disconcerting. Many drugs are known to affect time perception. In general, stimulants (e.g. amphetamine, caffeine) have been found to cause an overestimation of time and depressants (e.g. quinine, barbiturates) an underestimation (e.g. Adam, Rosner, Hosick and Clark, 1971; Frankenhaeuser, 1959). In addition, experiments dealing with sensory deprivation demonstrate that under conditions of isolation, duration may

be greatly underestimated (e.g. Crawford and Thor, 1967; Vernon and McGill, 1963). The finding that some persons can awaken themselves at a time decided upon before going to sleep (e.g. Omwake and Loran, 1933) and the temporal accuracy with which subjects carry out post-hypnotic suggestions (e.g. Stalnaker and Richardson, 1930), are remarkable observations in need of further study.

Bindra (1976) has recently advanced a theory which takes into account both the possibility of some neural timing mechanism as well as the effects of learning and experience. He hypothesized that "timing neurons", firing at regular intervals, act as pacemakers to define organismic time frames. Through experience with intervals of different durations, these neurons become organized into sets of "gnostic assemblies" each representing a particular duration and time-frame base. Thus a collection of temporal gnostic assemblies serve as a rough interval scale for making duration judgments and these assemblies are continually being modified through temporal experience. While Bindra's theory is descriptive and as yet lacking in empirical support, it is highly likely that both temporal experience and some physiological mechanism are involved in the ability to estimate time. Furthermore, an emphasis on cognitive variables does not necessarily imply that cognition occurs without a physiological substrate.

Cognitive Information Processing Approach

The second major approach to understanding perception of duration and the one most relevant to this investigation is the cognitive information processing approach. This theoretical model was initially presented in the late 19th century and has only recently been further elaborated by Ornstein in his book entitled On the Experience of Time (1969). Although results based on cognitive theorizing have not always been consistent and many of the hypotheses are in need of more thorough investigation, several researchers argue that at present it is a more promising approach than the sensory process model (e.g. Avant and Lyman, 1975; Ornstein, 1969; Vroon, 1970). Cognitive theorists tend to emphasize external stimuli as determinants of perceived duration. Temporal perception is conceived of as a mental construct dependent upon information processing, attention and memory.

Two main models are derived from the cognitive approach: the input register theory and the storage size metaphor. The former stresses the importance of the amount of information registered in consciousness in determining the duration experience (Fraisse, 1963) while the latter holds that duration experience is a function of the information remaining in storage (Ornstein, 1969, 1972). Ornstein, disenchanted with the earlier notion of input register theory in its limited applicability to short-term memory events, proposed the "storage size metaphor" which he claimed could account for not only

the amount of information reaching awareness but also the way in which that information is coded and stored. This distinction can be questioned, since it has been demonstrated that coding and storage processes are also involved in short-term memory processes (e.g. Lindsay and Norman, 1972; Miller, 1956; Neisser, 1967). However, the division of short and long time experience along the lines of a memory model seems valuable and could explain some inconsistent results for it could be expected that different stages of memory processing differentiate temporal experience.

Ornstein's storage size metaphor postulates that the experience of duration is a function of the amount of information remembered about that interval: "As the storage size increases, the duration experience lengthens" (Ornstein, 1969, p. 43), and anything altering the storage size will affect the experience of duration. This hypothesis was supported by a series of nine experiments in which subjects, unaware of the purpose of the experiment, estimated the duration of sensory stimuli as well as of tasks, using the paired comparison method. Several determinants of duration experience were studied: the input, the coding processes and the storage processes. Ornstein's experiments will be considered in detail given that this investigation has dealt directly with many of the cognitive variables he has studied.

In his first four experiments, Ornstein was concerned with the influence of two fundamental structural properties

of stimuli; the number of stimuli and the complexity of a stimulus or sequence of stimuli filling a given interval. His findings indicated that by increasing the number of auditory stimuli (tones) occurring in a given interval the duration experience was lengthened. He argued that temporal judgments were longer because more information was encoded and stored in long-term memory. When complexity of both visual and auditory material (e.g. figures differing in number of angles, coherent sentences vs. random sounds) was varied, the more complex stimuli also resulted in longer estimates of duration. Ornstein defined his more complex stimuli as also being "less well-organized" and interpreted these findings by assuming that it takes more space to store more complex items.

In his next two experiments, Ornstein studied another determinant of duration experience: the coding process. This was done by manipulating two variables: familiarity and categorization. Results demonstrated that subjects familiar with a motor task perceived duration as shorter than those not familiar with the task. This was interpreted as confirming the storage size metaphor; during a familiar task, less information enters consciousness which results in a decrease of storage size and thus perceived duration. Category was manipulated by providing subjects with different coding schemata for visual material (i.e. films of dance sequences). The more comprehensive code yielded shorter estimates. According to Ornstein, coding the information into fewer categories

provides for better organization which in turn reduces the storage size and shortens perceived duration.

In his latter experimental endeavors, Ornstein attempted to explore the effects of storage processes more directly by altering the size of storage of an interval independently of input. In one study using words paired with harsh sounds, duration estimates given in retrospect (2 weeks later) were found to be significantly shorter than those given immediately following presentation of the interval. Ornstein accounted for this time-order effect by postulating that with time passing, items drop out of storage reducing the storage size and shortening the duration experience.

Perhaps the most impressive and conclusive of Ornstein's studies is his last in which he demonstrated that storage size and thus perceived duration may even be altered by events following presentation of the stimulus. Subjects shown an ambiguous figure and later given a means by which to code it, perceived the interval as shorter than those who had no means of organizing the perceptual experience.

In summary, using a variety of experimental manipulations, Ornstein has made a most convincing case for the vital role of memory in the perception of duration. Nevertheless, there are many weaknesses in his experimental design and corresponding theoretical speculations, the most fundamental of which will be considered here.

The first and most serious criticism concerns Ornstein's

central explanatory concept of "storage size". Despite the fact that his framework is based entirely on a memory model, he failed to take into account recent advances in information processing theory. For instance, Ornstein describes storage as somewhat like a rubber band capable of expanding and contracting as a consequence of amount of information presented. Yet it is now well-documented that the number of items that can be stored in short-term memory is constant for each individual due apparently to the limits of short-term store in processing information. Thus memory capacity is fixed and does not entirely depend on the number of events that actually occur in a given interval (Block, 1974; Lindsay and Norman, 1972; Miller, 1956; Neisser, 1967). Ornstein's failure to distinguish between the information presented or perceived and information stored is due to the fact that he did not test for the amount of information in storage. This is the second major criticism of his work. Storage mechanisms are used to explain results and yet these are never systematically examined but only inferred. Thus the precise relationship between cognitive variables and subjective duration remains ambiguous.

Another aspect of ambiguity and third major weakness is Ornstein's definition of stimulus characteristics. For instance, his definition of "complexity" in terms of sensory organization or external structure can be questioned, for a more "complex" stimulus is not necessarily less organized.

This partially explains why the effects of complexity and organization have been contradicted by other authors (e.g. Block, 1974; Buffardi, 1974; Mulhern, Warm and Clark, 1974). A more startling inconsistency in findings has been the demonstration by several other investigators that amount of information processed is negatively correlated with duration experience (e.g. Burnside, 1971; Hicks and Brundige, 1974; Underwood and Swain, 1973; Vroon, 1970). The common observation that intense involvement in an activity often seems to make time fly-by attests to this possibility. Thus a fourth serious criticism of Ornstein's research is his neglect of attentional and motivational factors which may be highly influential determinants of subjective time experience.

Lastly, "the negative time-order" effect is a critical variable in Ornstein's theorizing as a major strength of his model lies in its ability to predict this phenomenon. However, while this effect was at one time considered to be universal, more recent literature indicates that it has not always been observed (e.g. Hogan, 1975; Mo, 1974; Vroon, 1970).

In conclusion, though many criticisms may be made of Ornstein's research, by adding new conceptual frameworks and empirical support to earlier speculations he has managed to present a model which makes strong argument for the importance of memory processes in perception of duration. The present thesis examined several stimulus characteristics as well as individual memory storage capacities in terms of their impact on time estimation.

Child Models of Time Perception

An unfortunate aspect of investigations of time perception in psychology has been that the adult and child literatures have remained entirely separate. If the sensory and cognitive processes underlying perception of duration are to be adequately understood, then efforts must be made to integrate theoretical and research findings from both populations. Furthermore, developmental studies of time estimation may allow us to determine which processes are implicated in the acquisition of this ability.

To date, there are few psychophysical studies that examine children's ability to estimate duration. The more significant empirical investigations were carried out in the last decade after a considerable amount of knowledge had been accumulated regarding the young child's acquisition of time concepts and temporal units. Research on the child's conception of time (e.g. Ames, 1946; Fraisse, 1963; Piaget, 1966, 1969), suggested that concepts of time and their use in the language are poorly developed before the age of 7 or 8 years. Consequently, few investigators examined the perception of time in younger children. But the absence of temporal concepts in children need not imply that they can not perceive time. In fact, it is likely that the child has the necessary perceptual apparatus before he has the verbal and cognitive skills required to communicate his time judgments. The nature

of the relationship between perception and conception of duration is still unknown as it has been impossible to examine the perceptual process directly. The psychophysicist can avoid the use of conventional time units and concepts, but he still must rely on some conceptual response measure from the subject. Thus far, technical problems have limited the number and scope of empirical investigations using simplified response measures which would serve to add greater clarification to the relationship between the conception and perception of time.

The discussion which follows offers a brief summary of theoretical models and research dealing with the young child's concept of duration. The review emphasizes developmental trends in temporal conceptual abilities that might be relevant to an investigation of time estimation. Subsequently, those core studies examining the young child's ability to estimate time are thoroughly reviewed. In the last section, studies dealing with the relationship between children's time knowledge (conception and perception) and other aspects of intellectual and cognitive functioning are discussed. These studies were considered in the light of what information they may provide for a better understanding of the cognitive and perceptual mechanisms involved in the ability to estimate time.

The Child's Conception of Time

Theoretical frameworks and research efforts concerning the child's conception of time were available from the following sources: psychoanalytic theory, Piaget's analysis of the development of temporal conceptual operations, and studies concerning the development of the use and comprehension of temporal language.

Psychoanalytic theory. Freud was not directly concerned with the problem of time perception. His major contribution was to suggest that the child's earliest experience of time is related to his physiological needs and that the ability to delay gratification is the crucial element responsible for acquisition of the time sense (Wallace and Rabin, 1960). The psychoanalytic view holds that time develops in the child once he is capable of suppressing frustrated primary needs by anticipating later gratification on the basis of past experience and imaginings of the gratification to come. Thus both memory for past events and ability to anticipate the future are necessary requirements. The development of the "reality principle" in the child and its significance for emergence of a time sense is stressed at various psychosexual stages of development (e.g. feeding schedules during the oral phase, toilet training during the anal phase). This theoretical formulation though lacking in experimental validation, has been generally accepted by other investigators including Piaget.

The Piagetian view. Our most thorough understanding of the developing capacity to perform temporal conceptual operations has been provided by Piaget (1966, 1969). During the sensorimotor stage, he employed observations of prelanguage children to provide an analysis of temporal operations. According to his formulation, between birth and 2 years of age, the infant's temporal experience involves seriation without conceptualization. At first, automatic sequential movements are performed in an egocentric "practical series". Once the child begins to learn to be able to delay gratification, he is able to take into account the ordering of external events but only insofar as they relate to himself ("subjective series"). By the end of the first year of life, seriation is objectified and the child is capable of transcending the duration of personal activity.

After the first year, the representative aspect of time begins to develop dependent upon memory (e.g. object constancy) and language acquisition. Using ingenious techniques of experimental manipulation, Piaget has demonstrated that this "representative series" proceeds in a very definite order. First, an understanding of object concepts is demonstrated, then spatial relations, then causal relationships and only finally is the young child able to perform temporal operations accurately. It is inferred that complex temporal relations are dependent on an understanding of the previous three concepts.

The preoperational child may nonetheless still confuse the relationship between time, space and speed. In making time judgments, he uses concepts of space or speed, but is unable to take into account more than one variable at a time. Thus at this preoperative stage, duration is equated with greater distance travelled or faster speed.

Two classic Piagetian experiments demonstrate the effects of speed on time estimation. When children were given the task of either drawing lines neatly or as rapidly as possible during intervals of identical duration, the majority of 4- to 6-year-olds thought that drawing rapidly took more time whereas advanced younger subjects and the majority of 10- to 13-year-olds judged the two intervals to be equal. In the second experiment, children observed the action of two trains which started and stopped simultaneously but travelled at different speeds. For the younger children the train that travelled further took more time. Lovell and Slater (1960) have replicated the former study and their results support Piaget's hypothesis that there is a steady improvement with age in ability to recognize that two intervals may be of equal duration (objective time) regardless of how they are spent (subjective time).

At what age then does the correct concept of duration emerge? It should be noted that while Piaget presented his observations in terms of "stages", that these are continuous rather than clear and distinct, particularly in the case of

the child's progress in the comprehension of time. Keeping this factor in mind, Piaget postulated that relatively constant regulations come into effect at the stage of articulate intuition or concrete operations (approximately 7 or 8 to 11 years) when there is conservation of speed. At this stage, decentration in relation to time is fully accomplished and the child can conceive of time as homogeneous and reversible.

Undoubtedly Piaget has made an outstanding contribution to our understanding of the growth of temporal concepts in the young child. His experimental approach, however, has many weaknesses. The Piagetian interview method is most susceptible to problems of experimental control and also to problems of misinterpretation on the part of the investigator and/or subject. Piaget's independent variables were not rigorously defined and the responses he obtained were verbal and trichotomous ("longer", "shorter" or "equal"). Bateman (1968) has criticized Piaget for his lack of clarity. Her stand is well-taken since the diverse interpretations of his work demonstrate his failure to be consistent and explicit. Another serious criticism concerns the complexity of the tasks used. Often the child is presented with an intriguing stimulus array, asked to answer questions which demand sophisticated intellectual operations, and in addition required to give a verbal explanation of his reasoning. While this may be appropriate for the child who has already reached the stage of concrete operations and is capable of such higher-order

abstractions and linguistic facility, the technique may be telling us very little about what the preoperational child does know about time. Piaget's approach does not allow for exploration of the time sense in the younger child, and as Farnham-Diggory (1966) has pointed out, it is also unsuitable for use with psychotic and brain-damaged children.

It may well be that due to the limitations of his methodology, Piaget has underestimated the young child's appreciation of duration. For instance, Fraisse (1963) who has studied Piaget's work in depth and carried out several of his experiments, disagrees with Piaget's central claim that the notion of time hinges on an articulate intuition of the relation between space and speed. He claimed that it is only on the plane of operations that the child makes this inverse relationship. Intuitively, speed can make events seem long or short for both adults and children. Furthermore, he postulated that what is acquired intuitively is the concept of duration itself. The perception of duration is determined by the number of changes perceived. At first an interval consists of nothing more than the changes that occur in it but gradually the child forms representations of intervals which become more and more independent of their content. Fraisse argued that a representation of duration appears before the point at which the child can take into account logical connections between time, distance and speed. By testing children as young as 5 years with a simpler technique

and tasks involving estimation of tones as well as familiar school routines, this investigation attempts to empirically test such a contention.

The development of temporal language. Studies concerned with delineating landmarks in the child's growth of time language (e.g. Ames, 1946; Bradley, 1947; Buck, 1946; Pistor, 1939; Springer, 1952) also suggest that the concept of duration appears rather late in development. In fact, the results of these studies were initially quite surprising as they demonstrated that the capacity to understand conventional time units and to use time words correctly develops later than was commonly believed. Although most authors seem to agree that temporal duration is the most difficult of temporal concepts to be mastered (e.g. Ames, 1946; Bradley, 1947; Pistor, 1939), there is some disagreement concerning when an adult-like conception of duration is reached. According to the studies summarized by Fraisse (1963), children are unable to estimate the duration of a conversation or to estimate clocktime with fair accuracy (i.e., within 20 min) until the age of 12. Bradley (1947) and Pistor (1939) claimed that duration is not fully grasped until at least age 10. Ames's (1946) study which is considered to provide the most reliable and thorough data for children 18 months to 8 years demonstrated that words implying duration and not just order become apparent in the 4-year-old's vocabulary, and that by age 7 or 8 he can communicate about clocktime. As may be apparent from the above

descriptions, one reason for the contradiction in findings is a lack of consensus of opinion regarding how to define an adult-like conception of duration; another, is the fact that many different means of inquiry have been used including anecdotal report based on observation, structured interview, questionnaire and a variety of other testing techniques (e.g. picture arrangement, story telling, analogies tests). Nevertheless, these methods have been able to provide some very basic and consistent developmental information.

There is now universal agreement that temporal expressions come into use in a relatively uniform sequence (Batesman, 1968). Considerable individual differences have been noted at all age levels (Ames, 1946) which may reflect varying rates of maturation or learning. Time concepts have been described as developing in the following way. First the child responds appropriately to the time word, next he uses it in spontaneous conversation, and lastly he is able to answer questions dealing with the concept. Another finding common to all these studies is that the growth of all time concepts proceeds from personal to conventional references and from specific to general application. Ames (1946) pointed out that children report the time at which an event occurred in terms of specific activity before they give actual clocktime units. Springer (1952) described the progression as: first the child tells time by daily, regularly occurring activities; then he uses unreasonable but numerical units; then he makes

reasonable but inaccurate judgments and finally, he reads the clock correctly. The hours are mastered first, then $\frac{1}{2}$ -hours, then $\frac{1}{4}$ -hours and only after clocktime is thoroughly understood is the child able to set it correctly and describe its functioning.

Thus, there has been considerable interest in designating growth stages of the child's expression and understanding of time concepts and temporal relations. The capacity to represent temporal characteristics has been shown to reflect specific developmental levels which are continuous and predictable. The way in which this representational scheme is related to the perceptual process itself, however, has yet to be determined.

The Child's Estimation of Duration

The development of temporal concepts provides the representative basis for the direct perception of the "quality", time. Time estimation methods involve examining the relationship between stimulus contextual variables and conceptual response circumstances in order to determine the underlying perceptual process involved (Goldstone and Goldfarb, 1966). Thus while time estimation studies attempt to examine the perceptual process more directly, the conceptual process can not altogether be bypassed. Methodologies do seem to differ in the degree to which they rely on verbal mediation (e.g. Adam, 1971; Clausen, 1950). Most investigators examining time perception

in young children have used short durations and methods of reproduction or production in order to minimize mediating cognitive variables.

The psychophysical approach to understanding time perception in adults has proved to be most valuable, yet only recently has this means of investigation been used with children. Available studies are few in number and fundamental variables such as the influence of age, sense modality and methodology are just beginning to be explored. So far, these studies have addressed themselves to three major questions. First, at what age is a child capable of estimating durations accurately? Second, can children when given feedback or specific training learn to be more accurate in their temporal judgments? Lastly, what perceptual and cognitive processes are involved in the estimation of duration?

One of the earliest studies to be concerned with time estimation in children differed from those which followed in that activity was a key independent variable. Axel (1924) was particularly interested in the effects of complexity of activity on duration judgments given by children 9 to 14 years and adults. An unexpected but striking sex difference demonstrated that females overestimated more than males. His finding that younger children overestimated the duration of simple tasks more than older children and adults has been confirmed in a number of other studies (e.g. Crowder and Hohle, 1970; Goldstone and Goldfarb, 1966; Smythe and Goldstone, 1957).

Gilliland and Humphreys' (1943) study is another early attempt but much more sophisticated methodologically and consequently often referred to in the later literature. Again age differences were a primary concern, however, these investigators were also interested in examining the effects of different methods and strategies of time estimation.

Fifth graders and adults estimated short vacant intervals of 9 to 180 seconds using reproduction, production and verbal estimation. It was found that adults were significantly more accurate than the children in the case of all three methods, but errors for both children and adults were reduced when subjects were allowed to count aloud in determining the interval. These findings suggested that children 11 years of age have still not fully internalized objective standards of duration and that learning of this skill continues to mature between adolescence and adulthood. Gilliland and Humphreys' results also implied that differences in method and strategies used by the subject may be important determinants of accuracy.

Smythe and Goldstone's (1957) research provides the most comprehensive investigation of age differences in perception of duration and represents the first attempt to examine the effects that direct feedback may have on temporal judgments. Three groups of subjects were used: boys and girls ages 6 to 14, college students and an elderly sample. Using a modified method of limits, tones of .02 to 20 seconds were presented in ascending and descending series and the subject was

asked to report whether each tone was more or less than one second. Midway through the task, subjects were given five consecutive one second durations and instructed to use these as a standard. Results demonstrated that with increasing age, the children's estimates became more like those of adults and were nearly alike by age 14. When estimates given by the 8- to 14-year-olds were examined, they did not differ appreciably from those given by either adults or the elderly (all subjects tended to overestimate). These children were also found to be able to correct their judgments when given information as to the absolute value of one second. The only difference observed within this older group of children was a decrease in intra-subject variability as a function of age. In contrast to the older children, 6 and 7-year-olds were extremely variable in their responding and their estimates were significantly different from the other groups. This age level involved the largest number of testing failures and the greatest intra-subject variability. In addition, these young children were unable to profit from information about the correct value of the standard.

Smythe and Goldstone concluded that 6 and 7-year-olds have not yet reached a developmental level necessary for reliable temporal measurement. They suggested that the ability to make absolute judgments of time emerges at age 8, matures slowly through adolescence, and remains fairly stable through adulthood and old age. This conclusion was confirmed by

another study in which feedback with and without kinaesthetic cues was provided (Goldstone, Boardman and Lhamon, 1958).

Goldstone and Goldfarb (1966) extended these findings by examining age differences in estimations of durations presented in two sense modalities using the method of constant stimuli. In combining their results with those obtained in the former two studies, they formulated the following general conclusions. First, children younger than 8 years were on the whole unable to provide accurate perceptions of duration and were highly variable in their estimations. Second, different methods resulted in different levels of accuracy. Production was easier than the method of constant stimuli and this method was easier than the method of limits. Children were able to be most accurate when given a production task involving kinaesthetic feedback. Third, sense modality had a significant effect on accuracy and variability of temporal estimates, the auditory mode being primary for perception of duration. Fourth, younger children overestimated time to a greater extent than older children and adults. This finding was a general one independent of sense mode and response requirements as well as method and other procedural factors. Lastly, the capacity to perceive time at younger age levels was dependent upon the complexity of the response requirements of the method employed.

These three studies represent a formidable contribution to our understanding of temporal duration in children. Unfortunately, however, the results of two later studies demonstrate

that Goldstone and Goldfarb's (1966) "general conclusions" are not at all as definitive as they may seem. In particular, their fundamental claim that failure to use and understand conventional time concepts reflects an inability to perceive time (i.e. respond differentially to different time intervals) has been severely challenged. In addition, their general statements regarding the ineffectiveness of feedback with younger subjects and the importance of kinaesthetic cues have been shown to be somewhat erroneous.

Crowder and Hohle (1970) hypothesized that a child can discriminate time intervals at an age considerably earlier than he is able to demonstrate this capacity by verbally identifying conventional time units. Accuracy of time estimation was investigated in preschoolers (mean age 5 years), first graders and third graders. Subjects attempted to reproduce the time required for a hidden toy to travel a path to a designated point. Half the subjects were given feedback information after each reproduction trial which provided information both about the direction and magnitude of error. That is, the tunnel hiding the toy was removed so that the child could observe how far away the lion was from his den. The second group attempted to reproduce the standard intervals (2.7 and 5.4 sec) without feedback.

Results demonstrated that all age groups in both feedback and no feedback conditions showed initial tendencies to underestimate the standard but all groups except the

preschoolers in the no-feedback condition showed increasingly accurate estimations over trials. In a second study, wherein preschoolers were simply presented with the standard interval in between test trials and either praised or not for their estimates, it was demonstrated that young children needed specific informational feedback in order to improve their judgments. Motivation or praise was insufficient. In fact, praise resulted in decreased accuracy of estimates reinforcing inaccurate responses.

Thus Crowder and Hohle (1970) demonstrated that children as young as 5 years can estimate time/intervals and make accurate judgments when given appropriate informational feedback. They attributed their results to a methodology which did not depend on any verbal or symbolic cues and offered concrete feedback. While most studies have given children the task of reproducing some arbitrary stimulus such as a tone, "the task used in the present study was more relevant to typical life situations and the instructions probably had more concrete meaning to the young children" (p. 306). Hermelin and O'Connor's (1971) study offers further support for the importance of methodological considerations in studies exploring time estimates given by young children. Although their task was one involving 2-category responses (short, long) for visual and auditory stimuli, they demonstrated that 5-year-olds were able to be more accurate when instructions were made highly specific and that the nature of instructions was a

critical determinant of whether or not young children "switched-in" to the duration dimension on a time estimation task.

In summary, the research on time perception in children has demonstrated that age, sense modality and in particular methodology are significant factors in determining the accuracy with which duration judgments are made. While it was previously maintained that children are not able to estimate duration accurately until the age of 8 (thus paralleling growth of temporal concepts) this assumption has since been seriously challenged. Studies so far indicate that whether or not the capacity to perceive time is reflected in performance on a temporal estimation task is highly dependent upon the nature of the task itself, instructions given by the experimenter and type of feedback provided. If investigators are to obtain a more thorough understanding of what children perceive about time and the mechanisms involved, then research suggests that methodology must be a central focus of these efforts.

Time Knowledge and Cognition in Children

In the series of studies which follow, the present investigator, using Ornstein's (1969) cognitive information processing model, attempted to examine cognitive and memory variables that may be related to the young child's ability to estimate duration. Thus of interest was the literature exploring the relationship between temporal estimation ability and facility in other areas of cognitive functioning. The

ability to perceive and conceptualize time correctly has been demonstrated to reflect general intellectual and cognitive growth. Evidence for this is available from studies correlating time tests with tests of intelligence and time research using subnormal and learning disabled populations.

The relationship between time knowledge and intelligence.

Goldstone and Goldfarb (1966) have commented:

Any mental function that develops in a systematic fashion according to a consistent schedule and involves varying levels of conceptual and logical complexity is likely to find its way into our intelligence tests (p. 457).

In fact, much of the research on time concepts began as a consequence of efforts to discern the mental age levels at which specific temporal items should be placed on IQ tests.

Engle and Hamlett (1950, 1952) examined correlations between the IQ measures on the Stanford-Binet and Buck's (1946) Time Appreciation Test. This time test was devised for use with adults and children not under 10 years. It consists of thirty questions concerning immediate orientation and definition of time phrases and relations. It is one of the few standardized tests available demonstrating high test re-test reliability. A high positive correlation was obtained between IQ and scores of temporal knowledge. These authors have suggested that Buck's time test may provide a rapid tool for screening intelligence.

Kahn (1966) investigated the relationship between degrees

of perceptual and cognitive organization and time orientation in children 8 to 11 years. Two measures of time orientation were used, a time estimation task and a time perspective task. For the former, subjects reproduced intervals of 3 to 10 seconds; for the latter, time span was determined using a projective technique of story telling. Perceptual organization was measured by calculating the degree of organization in responses to Rorschach cards. Cognitive organization represented increasing degrees of organization of subject's responses to a word association test. His most interesting finding was that time orientation was significantly related to cognitive organization and to a lesser degree to perceptual organization. Using results from the time estimation task, overestimation was associated with low organization and underestimation was related to high organization. Other studies have demonstrated that children of this age range generally tend to underestimate long intervals. Thus, Kahn concluded that the "normal" response on time estimation tests is associated with well-organized intellectual functioning. On the measure of time span, projecting into the future was related to high organization. While the measures of time were significantly related to one another, no positive relationship was obtained between measures of organization. Thus while the nature of the relationship between time and organizational factors is as yet unclear, there is some evidence to suggest that the organization of thought is a significant factor in time

functioning.

Time research using "subnormal" populations. In addition to research concerned with normative samples, several studies using brain-damaged children, the mentally retarded and other "subnormal" populations demonstrate that poor intellectual functioning is accompanied by deficits in understanding time.

Lovell and Slater (1960) compared the performance of "normals" and "educationally subnormal children" on a variety of Piagetian tasks. Their findings indicated that for the subnormal children, an understanding of simultaneity, equality of synchronous intervals, order of events, age and estimation of subjective time follows roughly the same sequence as in normal children, however, these stages are reached some years later. Concepts that developed in normal children between the ages of 8 and 10 years, were found to emerge between ages 12 and 17 in the subnormal group. More recently, Montroy, McManis and Bell (1971), using normal and retarded children matched for mental age (ages 6, 9 and 11) supported these earlier results. Similarly, Gothberg (1949) found that only after a mental age of 7 years could mentally retarded subjects answer questions about time beyond their own personal experience. His results demonstrated that logical sequences and differences in time duration cannot be understood until a child reaches a mental age of 10. The effects of specific training were found to be negligible in comparison to mental

age.

McNutt and Melvin's (1968) study is perhaps the most comprehensive effort to examine time estimation of retarded individuals. They compared the performance of retardates with age-matched non-retarded adults in reproducing durations of acoustic signals ranging from 1 to 29 seconds. While both groups underestimated the longer intervals, retardates showed progressively more underestimation than normal subjects at the two longest durations. This result was interpreted within the framework of Ellis' stimulus trace theory which postulates a short-term memory deficit in retarded individuals.

Mulhern, Warm and Clark (1974) suggested an alternate explanation of these findings. They proposed that the retardate's difficulty is one of organizing information. Retarded and non-retarded children of 9 to 11 years reproduced intervals of 3 to 15 seconds under two conditions. In the first condition, pure tones were presented and in the second, external structure for organizing the input was provided by modulating the intensity of these acoustic signals according to a regular pulsating rhythm. The results obtained in the non-modulation condition confirmed McNutt and Melvin's (1968) findings with adults. Reproductions by the retarded children became progressively shorter and less accurate than those of the non-retarded group as the stimulus duration increased. However, contrary to their prediction, both groups significantly increased their accuracy (i.e. longer reproductions)

when the input was modulated. It may be that these investigators were tapping a more fundamental aspect of the processing of temporal information. As already mentioned, several investigators have reported that within limits, perceived duration tends to be directly related to the number of stimulus changes occurring during the interval (e.g. Ornstein, 1969).

Farnham-Diggory (1966) has presented some interesting data concerning time estimates given by brain-damaged and psychotic children. The performance of these 7- to 16-year-olds was compared with that of a normal group matched for age, sex, IQ, race and socioeconomic status. Subjects estimated the duration of empty intervals (5, 10, and 15 sec) by drawing lines of different lengths. The time duration task yielded significantly longer estimates from the brain-damaged and psychotic groups than the normals. Within the brain-damaged group, IQ was negatively correlated to a highly significant degree with length of duration estimates. According to Farnham-Diggory, if IQ is taken to be a rough index of severity of brain-damage then this finding implies that the greater the brain-damage, the more slowly time seems to pass. Interestingly enough, she also postulated that 'poor organizational ability' (as reflected in IQ) may be responsible for the inaccurate judgments made by her brain-damaged subjects. However, in this case, the inability to organize information efficiently was associated with overestimation of empty intervals.

In summary, there is presently sufficient evidence to indicate that the ability to conceptualize time and to estimate duration is related to general intellectual growth, however, the precise nature of this relationship is as yet unknown. Studies with subnormal populations have suggested that perhaps memory and cognitive organization are important variables underlying the ability to conceptualize time accurately. One difficulty in using clinical populations for this type of research is that the cognitive and perceptual deficits of subnormal groups such as the retarded and brain-damaged are in themselves not thoroughly understood. This makes it exceedingly difficult to tap what factors may be responsible for their deficiency in understanding time. A more fruitful approach may be either to pursue research at this stage with normative samples or to use clinical samples wherein the underlying dysfunction is more clearly understood.

Time Research Using Learning Disabled Children

Time research using learning disabled children presents a similar problem. The label "learning disabled" has been used to describe any deficiency in learning. Children so described are distinguished from subnormal populations in that they have adequate motor ability, vision and hearing and are of average intelligence yet they cannot learn in the usual manner (Johnson and Myklebust, 1967). The term "temporal

"disorder" has been recently adopted by some educational psychologists to refer to any difficulties that a child or adult experiences in learning the significance of sequence and time (Bateman, 1968).

Though few empirical investigations have been carried out, there is some evidence to suggest that difficulties in understanding time are related to basic skill difficulties (primarily in reference to severe reading problems) and language disorders or oral language difficulties (Bateman, 1968). Unfortunately, many reports are anecdotal. For instance, temporal disorders are often mentioned as part of syndrome of larger disability categories such as dyslexia and aphasia (e.g. Efron, 1963b).

In most discussions of the relationship between severe reading problems and temporal disorders, the aspect of temporal sequencing has been stressed (e.g. Kahn and Birch, 1968; Rudnick and Sterrit, 1967). The significance that the perception of duration may have in the acquisition of language and reading skills has generally not been considered. An exception is a recent study by Edelstein (1971) in which fourth and fifth graders (matched on age and intelligence) were divided into three reading levels and given both a time questionnaire and a series of short time intervals to be reproduced (.33 to 1.10 sec). Edelstein hypothesized that performance of these three reading groups would differ given that the ability to read not only involves sequencing but aspects

of duration as well (e.g. connection of words by short time intervals, conditioning time in learning to identify configurations of words and fixation pauses). His results demonstrated significant differences between the reading groups on the time questionnaire but negligible differences for reproduced intervals. Those items of the questionnaire discriminating most amongst the readers dealt with the handling of conventional units of time (e.g. days of the week, reading the clock, judging suitability of time periods for daily events). However, when the performance of the two extreme reading groups were compared, significant differences were observed in variability of responding (i.e. standard error scores) on the time estimation task. Furthermore, the better readers who were more consistent in their judgments yielded higher scores on the time questionnaire. A further interesting finding was that those subjects receiving small group remedial reading instruction were significantly more accurate in reproducing intervals.

Thus Edelman's (1971) study suggested that perception of duration may be an additional temporal aspect important in the acquisition of reading skills, however, it also raised a number of questions. What in fact is responsible for variability in responding on a temporal estimation task? Is attention a key factor? In what way are temporal skills such as sequencing and duration related? Do temporal disorders underlie basic skill deficits in reading and language or vice

versa? Again the answers must lie in a more thorough investigation of the sensory and cognitive mechanisms involved in time perception and an analysis of the components involved in other basic skills.

Researchers have only just begun serious attempts to delineate those cognitive skills which may be important for an appreciation of duration. One question that has recently been raised is whether perception of duration is a lateralized function. There are some authors (e.g. Ornstein, 1972) who have suggested that time perception and judgment of duration in particular, is a right-hemisphere, non-verbal function. There is, however, no empirical support as yet for this assumption. Hicks and Brundige (1974) had left- and right-handed college students make verbal estimations of temporal durations during performance of recognition memory for words and faces. Their results did not support a lateralization of function hypothesis with respect to judgments of temporal duration. One difficulty seems to be that most methodologies used have relied heavily on verbal mediation. Efron (1963a) claimed that the left hemisphere is dominant for all temporal sequencing, both verbal and non-verbal, however, he was dealing with verbal codifiable material. It may be that certain aspects of time are more verbally linked than others. Not only does the relationship between time estimation and other temporal aspects (e.g. sequencing, knowledge of clocktime, temporal behavior) need further exploration but the link

between time perception and non-verbal, verbal and memory function is needy of clarification. This investigation attempts to examine the relationship between these variables and perception of duration in a normal population of children.

General Statement of Problem

The following investigation consists of two separate studies. Both deal with time estimation within the cognitive framework offered by Ornstein (1969).

In the first study, children and adults of different ages estimated the durations of tones. Then the structural properties of tone sequences were altered in order to examine the influence of stimulus contextual variables on time estimation. The critical questions asked were: Can children as young as 6 years estimate the duration of simple time stimuli using cross-modality matching? How do temporal judgments given by adults and children differ? What effects do such variables as stimulus rate, organization and familiarity have on the experience of time?

The second study focussed on young children and explored their ability to estimate both duration of tones and familiar school routines. Motivational factors that might influence estimates of familiar activities (e.g. task pleasantness, task difficulty) were systematically examined. In addition, various

cognitive and behavioral measures were investigated as possible predictors of the children's performance on both estimation tasks. This procedure allowed for an analysis of those cognitive and perceptual mechanisms that may be related to the ability to estimate time.

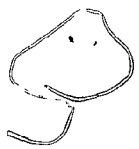
EXPERIMENT 1

The purpose of the first study was to examine the precision with which various age groups estimate duration of simple auditory stimuli and the ways in which altering the structural properties of these stimuli influence temporal judgments. The investigation was divided into two phases.

In Experiment 1A, the primary question being asked was: Can children as young as 6 and 7 years (grade 1) demonstrate the ability to estimate duration in the absence of direct feedback, if given simple time stimuli and required to make a response geared to their abilities? Thus pure tones were presented for short durations, a standard comparison interval was given at the outset of each trial and subjective estimates of variable tones were made by matching the length of a line with length of perceived duration. This type of cross-modality matching with a standard and the apparatus employed were particularly designed for use with young children. The method eliminated the use of numbers and did not require the subject to possess any knowledge of clocktime. Because no results using this response measure could be found in the literature on duration, several other age groups were tested. Young adults were chosen as the primary reference group because the results of most time estimation studies of this sort have been based on adult samples. In addition, 9 and 10-year-olds (grade 4) and a group of elderly subjects were

included in an effort to obtain further information regarding the development of temporal estimation ability.

At the outset, it was questionable as to whether or not the 6 and 7-year-olds would be able to respond differentially to durations using this technique. Assuming that they could, the following age group differences were expected. First, based on the findings of previous studies, it was hypothesized that the youngest children would be the most variable in their responding and that they would have the greatest difficulty making their judgments proportional to the standard. Thus their time estimates would be least accurate. Second, it was expected that the 9 and 10-year-olds would be more accurate and consistent than the younger group of children and that their performance would more closely approximate that of young adults. No definite predictions were made concerning the elderly sample. Time estimation studies using older subjects have been few and the results so far remain contradictory. Smythe and Goldstone's (1957) elderly sample gave estimates that were not significantly different from those of adults, yet Goldstone, Boardman and Lhamon (1958) found the elderly to be as variable and as inaccurate as their 6-year-olds. There is some suggestion that the processes involved in the perception of duration are reversible and that they may develop in a curvilinear fashion across the life span. Thus, by including these different age groups, the young child's ability to estimate short durations was investigated in a



broad developmental context using a simplified psychophysical methodology.

In Experiment 1B (which included all but the elderly sample), certain structural properties of the stimuli were varied and the effects of these manipulations examined within the cognitive framework offered by Ornstein (1969). Using the procedure already outlined, auditory material now differed along three stimulus dimensions: amount of information (i.e. three stimulus rates), organization (i.e. evenly spaced pulsating tones or rhythmic sequence) and familiarity (i.e. familiar melody or unfamiliar melody). Speed was combined factorially with the other two variables for the purpose of investigating interactive effects.

Psychophysical studies with young children have rarely gone beyond looking at the effects of very short durations (typically 1.0 sec) on accuracy and variability. Piaget's (1969) work on the maturation of temporal operations implicates speed as a critical determinant of children's estimates of duration but within quite a different experimental paradigm. Thus hypotheses concerning the effects of these higher-order structural variables and their interactions were based on experimental findings to date with adults. The utility of applying the cognitive model to examine temporal processes in young children was assessed.

According to Ornstein, the experience of duration of an interval in retrospect is a cognitive construction based on

the number of events stored and retained in long-term memory. Experimentation so far suggests that this generalization is warranted under conditions wherein simple tasks are presented (i.e. tasks that do not involve higher-order levels of information processing) and wherein the subjects' disposition towards the stimulus material (i.e. attention, motivation) can be assumed to be relatively constant. For instance, Frankenhaeuser (1959) varied the presentation rate of acoustical stimuli filling intervals of 13-72 sec and found that estimated durations increased with the sequence speed of the clicks. Her findings have been confirmed repeatedly (e.g. Jones and Maclean, 1966). Similarly, Hintzman (1970) presented subjects with a series of words that varied both in frequency of repetition (1 to 5 repetitions) and exposure duration (2 to 6 sec). Temporal estimates were significantly affected by both these factors confirming a positive correlation between number of intervening stimuli and perceived duration. Buffardi (1971) investigated the "filled duration illusion" using auditory, tactual and visual stimuli, by systematically varying the number and placement of intervening elements within a given interval. Number of intervening elements was demonstrated to be the most important factor. Durations with more elements were judged longer than durations with fewer elements and the identical illusion occurred in all three modalities.

These studies all demonstrate that apparent duration

increases as a function of amount of information transmitted. However, some authors have suggested that when higher-order levels of information processing are required, the same relationship may not hold. It is impossible to discern from Ornstein's experiments whether a distinction between presented and processed information is necessary as he offers no check on what the subject does with the input. Vroon (1970) duplicated the essential features of Ornstein's first study using tones and obtained similar results. However, in a second experiment when subjects were required to respond actively to the stimuli by making binary choices, duration estimates decreased with the number of processed bits. Burnside (1971) and Wilsoncraft and Stone (1975) have also argued for a distinction between stimulus input, stimulus output and different types and levels of information processing. In accordance with Vroon's results, they have postulated that an increase in the number of substeps required to process information reduces duration experience, whereas an increase in the amount of information remembered lengthens perceived duration. Block (1974) has demonstrated that when lists of unrelated words of varying length are presented within the same duration interval, the longer word lists are estimated as longer despite the fact that the number of items recalled are the same. However, he also presented subjects with a recognition task and found that more words were recognized from the longer lists. Thus storage size and hence perceived

duration may be related to the number of items input during the interval, the number of items output on a memory test after the interval has passed or any processing done to transform the input items into different storage items. These complex effects may occur as a result of introducing higher-order variables such as organization and familiarity.

In an attempt to minimize the effects that higher levels of information processing might have on duration judgments, the present investigator used a paradigm similar to that employed by Ornstein (1969) in his first series of experiments. That is, rather than using complicated tasks, subjects were passive recipients of simple auditory tone sequences. Thus it was hypothesized that Ornstein's basic premise would hold and that manipulations of stimulus rate would result in longer temporal estimates when the number of discrete elements was increased. Interactive effects have not been systematically examined by previous investigators. Therefore, the way in which differences in speed might influence duration estimates of material differing in organization and familiarity, remained an open question.

Experimental findings regarding the effects of organization and familiarity are more difficult to sort out because experimenters have defined these terms differently, tasks used have varied widely in complexity, and motivational and attentional variables can not be easily ruled out. Ornstein defined his organized tasks as being less complex (i.e. fewer

experiential units) and postulated that when stimulus material can be more easily chunked and stored, duration experience shortens. To equate "reduction of information" with organization is opposed to Mulhern, Warm and Clark's (1974) view that more variations or changes occur with rhythmic organization of stimuli. Block (1974) varied the organization of verbal material while keeping the number of events and duration of exposure constant, by blocking words of the same semantic category together or interspersing them within the series. In direct contradiction to Ornstein's findings, duration judgments for the more highly organized material were significantly longer. In addition, subjects presented with the organized word list recalled more words correctly than those given the less organized material. Thus the results are still supportive of Ornstein's theoretical premise, since an increase in organization resulted in more items being retained in storage. Information processing theory (Neisser, 1967; Lindsay and Norman, 1972) supports Block's (1974) results in that increases in organization of material has been demonstrated to increase long-term memory. In the study which follows, rhythmic auditory tones of the same frequency were presented in the "organization" condition and pulsating tones of identical duration defined the "regular" condition. Thus more highly organized material involved grouping as well as greater stimulus variation. It was hypothesized that the more organized auditory sequence would be estimated as shorter.

Few experiments have explored the influence that familiarity may have on duration experience. Ornstein manipulated this variable by asking subjects to estimate the duration of a well-practised task and others to give judgments of a task that was novel. He maintained that the more familiar task was judged to be shorter because less information was processed and hence the storage size was reduced. In contrast, however, Warm and McCray (1969), carried out an experiment in which subjects wrote down and estimated the exposure duration of tachistoscopically presented words that varied in length as well as in frequency of occurrence (defined by Thorndike and Lorge). Subjects estimated the duration of the more familiar words to be greater than those of lower frequency. A significant interaction with word length indicated that this difference was greater for the longer words. These authors explained their findings by suggesting that more rapid identification of familiar words freed selective attention for other cognitive tasks such as rehearsal or paying attention to the passage of time, thus lengthening perceived duration.

Avant and Lyman (1975) hypothesized that even during the initial stages of visual processing when attentional mechanisms are not operative, differences in subject's familiarity with letters, words and nonwords would generate differences in apparent duration of tachistoscopic flashes. In a series of prerecognition experiments, they demonstrated that the

shortest apparent duration accompanied the most familiar stimuli thus obtaining the same results as Ornstein. However, when more stimulus exposures were given on early trials, pre-experimental differences in stimulus familiarity were reduced which in turn lessened apparent duration differences among stimuli on later trials. In reconciling their results with those of Warm and McCray (1969), Avant and Lyman (1975) speculated that perhaps once stimulus identification is completed and attentional control mechanisms are operative, the direction of influence of familiarity on temporal coding reverses.

It is exceedingly difficult to compare the results of these latter studies with Ornstein's findings because length of duration, stimuli being estimated and definitions of familiarity differ so widely. The way in which attentional mechanisms might influence judgments of duration is as yet unclear. However, temporal estimation studies which have dealt exclusively with such variables as interest (e.g. Loehlin, 1959), boredom and monotony (e.g. Burton, 1943), success and failure (e.g. Harton, 1939), and goal attainment (e.g. Filer and Meals, 1949; Meade, 1963), attest to the powerful influence that motivation may have on perceived duration. Ornstein (1969) claimed that he need not concern himself with motivational factors because his subjects were unaware of the purpose of his experiment. This may be why his results are in accordance with Avant and Lyman's prerecognition studies. Woodrow's (1951) study lends some support to Ornstein's claim.

Subjects were trained either to pay attention to the stimulus characteristics of auditory stimuli or to the passage of time. The estimations of time were much longer for the subjects who concentrated on the experience of duration than for the other subjects. Nevertheless, Doob (1971) has argued that whether or not this "drive" factor can be excluded from even the most classic experiments remains entirely questionable.

In the present investigation familiarity of stimulus material was varied by presenting subjects with both a familiar melody and an unfamiliar melody. The novel melody was constructed by randomizing the notes (i.e. pitch) of the former but maintaining the same rhythm. This operationalization of familiarity more closely paralleled that used by Avant and Lyman (1975) and Warm and McCray (1969) in that familiarity was an a priori characteristic of the stimuli rather than being induced by exposure. Due to the conflicting nature of previous results and the dangers of generalizing across studies, no particular hypothesis was postulated regarding the influence of familiarity on duration estimates.

The procedure used in the present study departed from Ornstein's in that subjects' awareness of the purpose of the experiment was a necessary adjunct to using young children and employing a repeated measures design. Subjects, however, were instructed to pay attention to the stimuli presented and to refrain from using any overt strategies (e.g. counting, tapping, paced breathing, etc.). A further confounding that

may occur when the purpose of a time experiment is not concealed, is that subjects may use higher cognitive processes such as logic and reasoning to determine their duration estimates. Because in this second phase, the present investigator was not primarily interested in how accurately subjects estimate durations but rather how various conditions effect the subject's perception of time, this was an issue of concern. Some investigators (e.g. Loehlin, 1959) have dealt with this dilemma by requiring the subject to make two estimates, one of how long the time seemed, and one of how long he thought it actually was. A drawback of this technique, however, is that it gives the subject a cognitive set to make a distinction between the two. In addition, young children would probably be unable to make such a differentiation. Thus in the following study, in order to assess the importance of motivational factors, young adults were given a follow-up questionnaire.

EXPERIMENT 1A: Age Differences in Duration Estimates of Tones

MethodSubjects

A total of 98 subjects from four age groups (grade 1, grade 4, young adult and elderly) participated in this study. There were 24 grade 1 children (12 male, 12 female) with a mean age of 7 years, 1 month and 29 grade 4 children (15 male, 14 female) with a mean age of 10 years, 3 months. The children were randomly selected from Westminister Elementary School located in Côte St. Luc, a middle-class suburb of Montreal. The only selection criterion was that all children have at least average intelligence as measured by the Otis Lennon Mental Abilities Test. This eliminated two children from the initial subject population of 100. The young adult group was comprised of 30 McGill University undergraduate students (15 male, 15 female) who volunteered to participate. The 15 elderly subjects (4 male, 11 female) ranged in age from 72 to 92 years with a mean age of 82 years, 3 months. They were all nursing home residents who had been classified as being of "sound mind and body;" those who volunteered and who were judged to be adequately alert in a preliminary interview participated in the study.

Apparatus

All subjects used the same measuring device to indicate subjective estimates of temporal duration. The apparatus (see Figure 1) was a rectangular board, 121 cm x 35.5 cm, containing two identical parallel slits 5 cm apart. The horizontal slits measured 96 cm x 2.5 cm and were backed by red translucent plastic to prevent the subject from being distracted. A plastic handle was available at the left corner of each slit to enable subjects to pull out a yellow measuring tape which was secured to the back of the board. The tapes were easy to pull but remained in place once pulled out. The numbers on the tapes faced the experimenter who sat behind the apparatus to record the length of the tape pulled out by the subject. The top tape was used to measure the standard interval and its length was set at 48 cm. A nail located at the midpoint of the top slit prevented it from being made any longer. In contrast, the bottom tape was always used to measure a variable interval any distance along the 96-cm slit.

Stimuli

Tones of similar frequency (262 Hz) but different durations were generated by a PDP-11 computer. Subjects were presented with a series of 14 tone pairs in which a standard tone was always followed by a variable tone. A trial included a knock (which served as a ready signal), 2 sec of silence, a standard 12-sec tone, 3 sec of silence, and a variable tone

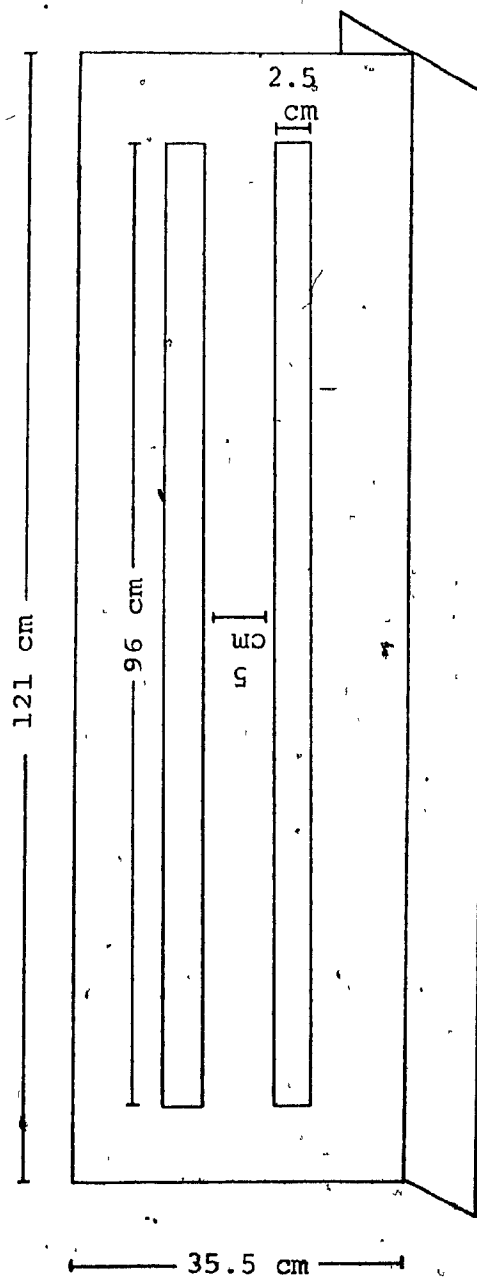


FIGURE 1. Time estimation apparatus.

of 3, 6, 9, 12, 15, 18 or 21 sec. Each tone pair was presented twice, and the 14 trials were randomized on audio tape in 10 different orders of presentation. The tones were played at 70-80 db through a Sony TC-800 taperecorder to two sets of earphones, one for the subject and the other for the experimenter.

Procedure

The experiment was conducted in quiet rooms devoid of visual displays or rhythmic sounds that might have aided timing. All subjects were seen individually for a 15-min session and were randomly assigned to one of the 10 presentation orders. They were asked to remove their watches and told that they were participating in a time experiment which was not related to clocktime. The instructions for the adult subjects were as follows:

This device is used to measure time. By pulling on these tapes you can make lines of different lengths to represent the durations of tones. There are two time lines which correspond to the two tones that you will hear through these earphones each time I turn on the taperecorder. Each pair of tones is preceded by a knock to signal you to be ready. The top tape is used to measure the first tone which is always of the same duration. The length of that tone has been decided for you and you must always set it at the half-way mark (experimenter demonstrates). The second tone, however, may be any length at all and you have to decide where to put the bottom tape depending on whether you think the second tone is shorter, equal or longer than the first (experimenter moves bottom tape to demonstrate). On each trial, you are required to pull out first the top and then the bottom tape but not

until you've listened carefully to both tones and the taperecorder has been turned off. Once you've made your judgments, I will signal you as to when to replace the two tapes to their starting position so that the next trial can begin immediately. Are there any questions?

Since the purpose of this study is not to find out how accurate people can be in estimating time, but rather to investigate how they feel the passage of time, I would like you to refrain from using any strategies that might help you to differentiate the duration of the tones. You are asked to listen carefully to the tones and to feel the time passing.

Instructions were modified somewhat for the children. The task was presented as a game in which the "time machine" was used to measure "how long sounds last for." Children were urged to "make the line exactly how long the sound was" and a demonstration trial was given to aid the children in equating length of line with length of tone. Prior to the estimation task, each child was tested to ensure that he understood the concepts "longer", "shorter" and "same". Between judging the standard and variable tones the child was prompted with the question, "Now was the second sound longer, shorter or the same as the first?" If the subject said "longer" ("shorter"), the experimenter replied, "Show me exactly how much longer (shorter)."

Before the testing period, the intensity of the sound in the earphones was checked. The apparatus was placed on a table and the subject sat facing it so that the time lines were at eye level. The experimenter sat behind the apparatus, observing the subject and remaining as non-expressive as

possible. After each trial, the tape recorder was stopped for the subject to make his judgment and for the experimenter to record it.

Data Analysis

Subjects' duration ratings were analyzed individually as well as by age group in a fashion typical of psychophysical studies wherein regression analysis is used to explore the relationship between changes in the magnitude of some physical property of a stimulus and corresponding changes in sensation magnitude (e.g. Gescheider, 1976). Regression analysis was chosen in order to include two extraneous variables in addition to the tone duration as predictors of temporal judgments. Whereas psychophysical studies have demonstrated that adults can take into account the duration of physical stimuli when making subjective estimates (e.g. Gregg, 1951; Ross and Katchmer, 1951; Gescheider, 1967; Michon, 1967), such has not yet been demonstrated with young children. Thus, an analysis was used which would allow one to explore possible continuous secondary variables that children might use in making their judgments.

The criterion or dependent variable was the estimate of the duration of the variable tone, represented by the length of the bottom tape on each trial. Given the typical finding that the distribution of temporal judgments is severely positively skewed (e.g. Carlson and Feinberg, Doehring, 1961,

1968; Stevens and Gallanter, 1957; Thomas and Brown, 1974), all judgments of duration (measured in cm) and actual intervals (indicated in sec) were transformed into natural log units. The independent variable of primary interest was the clocktime duration of the variable tone log transformed ("Time"). The two additional predictors were trial number ("Trial") and the logarithm of the tape setting for the variable tone on the previous trial ("last R"). Trial was included to determine the effect of practice or fatigue. Last R was used to investigate possible sequential effects of contrast and assimilation which have been noted in other psychophysical investigations (e.g. Holland and Lockhead, 1968; Ward and Lockhead, 1970, 1971).

Age group was not included as an independent variable in the group regression analyses. Thus, a two-way analysis of variance (age x tone length) and Newman-Keuls comparison tests were used to examine the interaction between age group and tone length. These tests made it possible to ascertain the precision with which children and adults of different ages discriminate tones of different durations.

Results

Group Analyses

Results for the group stepwise regression analyses are displayed in Table 1. The principal finding demonstrated a strong positive linear relationship between apparent duration and actual time. For all age groups, the best single predictor of temporal judgments was the clocktime duration of the variable tone. Time alone accounted for 63%, 72%, 84%, and 57% of the overall variance in responses made by grade 1, grade 4, young adults and the elderly, respectively. The importance of the Time variable was further confirmed by the fact that the F value for Time taken at the last step of each analysis, was significant ($p < .001$) for all age groups.

Table 2 provides a summary of the best fitting regression model for each age group. A model was defined by those predictor variables for which F was significant at the last step. Time combined with an additional independent measure gave the best predicted temporal estimates of the grade 1 children and the elderly.

Trial and last R added little predictive power to the regression equation. As shown in Table 2, the R^2 was only minimally increased with the addition of these variables. However, probably due to the fact that the group analyses were based on the results of a very sizeable N, F values at the last step for Trial and last R occasionally did reach

TABLE 1

Group Regression Analyses for Duration Judgments
of Tones by Four Age Groups

Age Group	Variable	Simple r	Multiple R	R Square	F To Enter	Usefulness
Grade 1 N=24	Time	0.796	0.796	0.633	577.225***	10.589
	Last R	-0.031	0.797	0.635	1.917	0.035
	Trial	-0.029	0.797	0.635	0.731	0.013
Grade 4 N=29	Time	0.847	0.847	0.717	1016.845***	11.521
	Trial	-0.111	0.849	0.720	7.126**	0.080
	Last R	0.026	0.850	0.722	1.746	0.019
Young Adult N=30	Time	0.919	0.919	0.844	2264.690***	13.619
	Last R	0.065	0.920	0.846	7.047**	0.042
	Trial	-0.044	0.920	0.846	0.537	0.003
Elderly N=15	Time	0.753	0.753	0.567	267.662***	10.525
	Last R	0.170	0.760	0.577	3.082	0.118
	Trial	0.074	0.760	0.578	0.248	0.095

***p < .001

**p < .01

*p < .05

TABLE 2
Best Fitting Model Derived from Group Regression Analyses
for Duration Judgments of Tones by Four Age Groups

Age Group	REGRESSION COEFFICIENT					
	Time (b_1) ^a	Additional Predictor (b_2)	Constant (b)	Multiple R	Se	F ^b
Grade 1	0.602 ± .049	-	1.060	0.796	0.258	576.329***
Grade 4	0.636 ± .039	-0.003 (Trial)	1.052	0.849	0.223	519.345***
Young Adult	0.892 ± .037	0.024 (Last R)	0.691	0.920	0.214	1145.987***
Elderly	0.694 ± .082	-	0.972	0.753	0.339	272.887***

***p < .001

^aThe quantity following the (+) or (-) is the 95% confidence limit.

^bCumulative F for best fitting model.

significance. Trial was significant in the case of the grade 4 group, $F(1,402) = 7.13$, $p < .01$. The negative correlation coefficient between trial and duration estimate indicated that the children's duration estimates became shorter as they progressed through the task. The significance of last R in the young adult group, $F(1,416) = 7.05$, $p < .01$, suggests the operation of sequential dependencies within this age group and the positive correlation coefficient indicated that responses were assimilated to the value of the immediately previous response.

According to Darlington (1968), the usefulness value (which is obtained using the formula $F(\frac{1-R^2}{N-n-1})$, where F is the tolerance F given in Table 1, N the number of subjects, and n the number of independent variables) measures the unique contribution made by each variable and may be considered to be the measure of 'greatest interest among those that have been used to indicate the relative "importance" of a predictor variable. Using this index, the importance of Trial and last R as independent variables remained very secondary. As shown in Table 1, the usefulness values for these two variables were always low relative to the Time variable. Thus the group regression analyses indicated that Time was the most significant predictor of duration estimates given by all age groups.

The low standard error scores obtained from the first step of the group regression analyses (where Time was the only independent variable) indicated that subjects in all age groups

were able to be consistent in their temporal judgments of the variable tones (grade 1, $Se = .26$; grade 4, $Se = .24$; young adult, $Se = .22$; elderly, $Se = .34$). Average slopes taken from the first step were: grade 1, $b = .60$; grade 4, $b = .64$; young adults, $b = .89$; and elderly, $b = .69$. In the context of the present study, the slope is an index of proportionality of temporal judgment (i.e. ability to take into account the standard). A slope of 1.0 represents the ideal case where the estimate given by the subject increases in exact proportion to increases in the duration of the presented interval. Because the data in this study have been log transformed, the slope is equal to the exponent of Stevens' (1962) psychophysical power law.

For the purpose of further exploring the relationship between Time and duration estimations across and within age groups, a two-way analysis of variance (age group $\times$ tone length) and Newman-Keuls multiple comparisons were carried out. Table 3 presents the analysis of variance which yielded a significant main effect for tone length, $F(1,94) = 471.98$, $p < .001$, and a significant interaction between tone length and age group, $F(3,94) = 5.38$, $p < .01$. Due to the repeated measures design and consequent inability to assume homogeneity of covariance, conservative degrees of freedom were used (Winer, 1962). Tests of simple effects yielded a significant main effect for tone length in the case of all age groups (grade 1, $F(1,94) = 93.20$, $p < .01$; grade 4, $F = 122.56$,

TABLE 3

Two-Way Analysis of Variance of the Effects of Tone
Length on Duration Judgments by Four Age Groups

Source of Variation	df ^a	Mean Square	F
Age Group (G)	3	0.2509	2.10
S(G)	94	0.1199	
Tone Length (R)	6(1)	17.2905	471.98***
RG	18(3)	0.1973	5.38**
S(RG)	564(94)	0.0366	

***p < .001

**p < .01

^aNote that conservative degrees of freedom were used in testing.

$p < .01$; young adults, $F = 249.19$, $p < .01$; elderly, $F = 74.84$, $p < .01$. The Newman-Keuls multiple comparison test was applied to the data of each age group to ascertain precisely which variable tones were judged different from the others (see Appendix A). In the case of the grade 1 sample, all tone duration comparisons differed from one another with the exception of the 12- and 15-sec tones, $Q = 1.06$, $k = 2$, $df = 94$, $p > .05$, and the 18- and 21-sec tones, $Q = 2.58$, $p > .05$. Grade 4 children performed better, their only difficulty was distinguishing the 12-sec from the 15-sec tone, $Q = 2.46$, $p > .05$. The elderly had the most difficulty, failing to discriminate the 12- from the 15-sec tone, $Q = 2.46$, $p > .05$, the 15- and 18-sec tones, $Q = .93$, $p > .05$, the 15- and 21-sec tones, $Q = 2.42$, $p > .05$, and the 18- and 21-sec tones, $Q = 1.49$, $p > .05$. Young adults discriminated all variable tones from one another (p 's $< .05$).

Figure 2 depicts the mean judgments of duration given by the four age groups for the seven variable tones. Mean tape setting was plotted against clocktime duration of tones. log log coordinates were used to produce a linear graph. Young adults tended to judge variable tones of 3, 6, 9 and 12 sec as being shorter than did the other three age groups. The graph also demonstrates that the young adults' mean estimate of the 12-sec variable tone was closer to the 48-cm length set for the 12-sec standard tone than judgments given by the other three groups. Grade 1, grade 4 and the elderly all made the 12-sec tone longer than the standard which

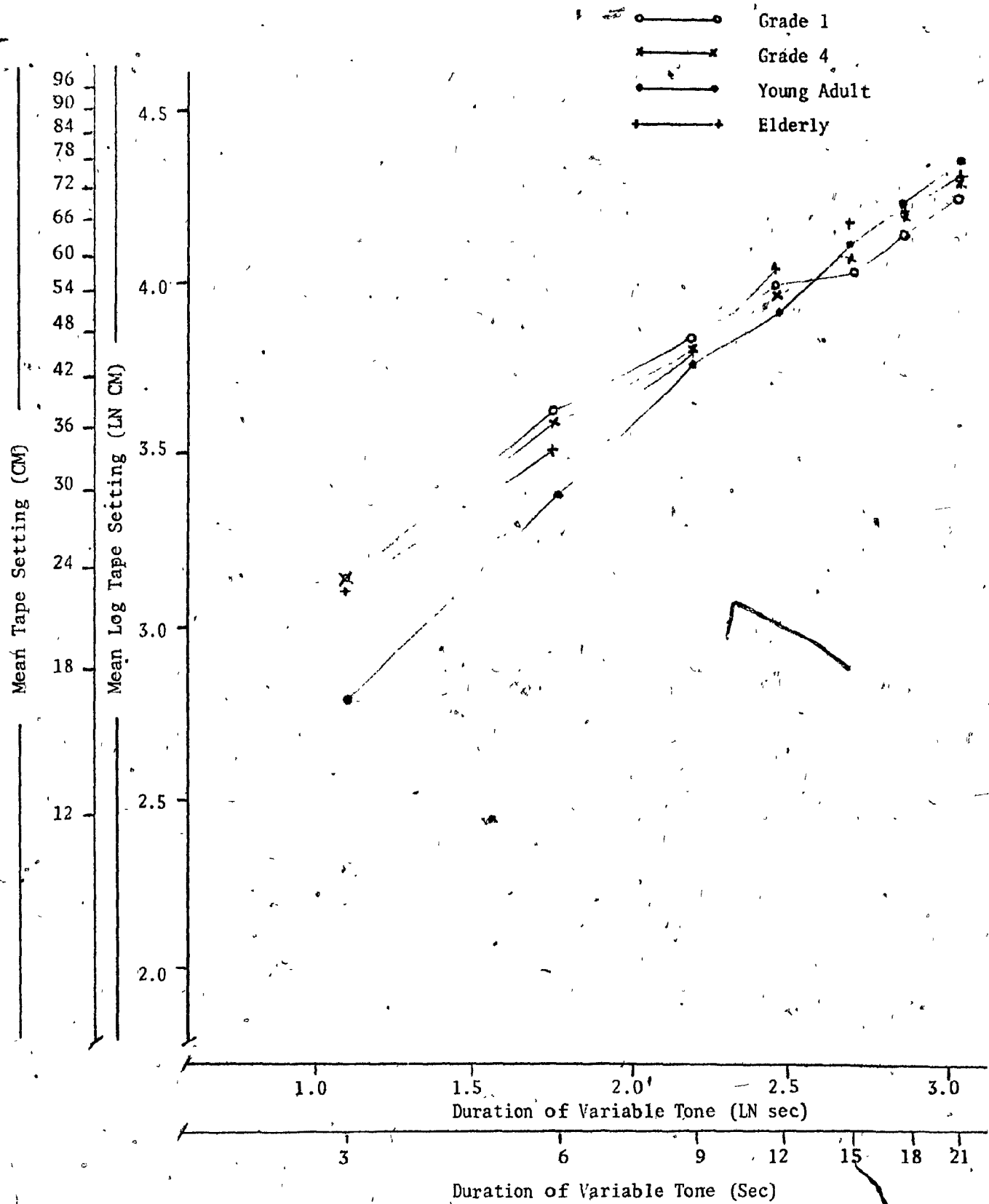


FIGURE 2. Mean judgments of duration of variable tones for four age groups.

indicates that for them, there was a stronger time-order effect.

Thus the group analyses indicated that all age groups based their time judgments on the actual duration of the variable tones. Age groups did differ, however, in their ability to distinguish between tones of different lengths. The elderly failed more comparisons than the children, whereas the adults significantly discriminated all durations from one another.

Inter-group Comparison of Individual Results

Individual regression analyses were performed on the 14 time judgments given by each subject. The degree of between-subject variability in this experiment may be appreciated by examining the summary of each individual's results provided in Appendix B.

When the best fitting regression model was calculated for each subject individually using the same predictor and criterion variables as in the group stepwise analyses, Trial and Last R proved to be significant predictor variables in only 9 of the 98 cases. For all remaining subjects, Time was the best single predictor of temporal estimations; this variable was significant in all 98 cases. In the individual regression analyses a more conservative cut-off value was employed when defining the best fitting model, $F(1,10) = 6.55$, $p \leq .01$, in order to compensate for bias towards finding

significance when using a stepwise procedure. This bias becomes more pronounced as the number of observations decreases, as is the case in the individual analyses.

Of additional interest is an examination of individual slopes and standard error scores. When standard error scores were calculated for each subject and averaged across each age group, they were considerably smaller than those taken from the group analyses. Mean standard error scores accounting for within-subject variability were: grade 1, $Se = .20$; grade 4, $Se = .17$; young adult, $Se = .16$; elderly, $Se = .20$. Table 4 presents a one-way analysis of variance applied to these data which yielded a significant main effect due to age group. When age groups were compared using the Newman-Keuls multiple comparison test (see Appendix C), results indicated that young adults were significantly less variable in their responding than both grade 1 subjects, $Q = 3.47$, $k = 3$, $df = 94$, $p < .05$, and the elderly, $Q = 3.96$, $k = 4$, $df = 94$; $p < .05$.

Slopes taken from the individual regression analyses were also subjected to between-age group comparisons using a one-way analysis of variance. As shown in Table 5, there was again a significant main effect for age group. A Newman-Keuls multiple comparison test (see Appendix D) demonstrated that young adults differed significantly from grade 1 children, $Q = 5.84$, $df = 94$; $p < .01$, from grade 4 children, $Q = 5.18$, $df = 94$; $p < .01$, and from the elderly, $Q = 3.95$, $df = 94$; $p < .05$. The slope for the young adults more closely

TABLE 4

One-Way Analysis of Variance of Standard Error Scores
for Duration Judgments of Tones by Four Age Groups

Source	SS	MS	df	F
Age Group (G)	0.035	0.012	3	3.557*
S (G)	0.309	0.003	94	

TABLE 5

One-Way Analysis of Variance of Slopes for Duration
Judgments of Tones by Four Age Groups

Source	SS	MS	df	F
Age Group (G)	1.290	0.430	3	8.565***
S (G)	4.721	0.050	94	

* $p < .05$

*** $p < .001$

approximated a slope of 1.0 and thus indicated that they were better able to be proportional in their time judgments than the other three age groups.

Variability within each age group and between age groups is demonstrated graphically in Figure 3 where the slope for each individual subject is plotted against his standard error. The graph explains the results of the one-way analyses of variance on these two measures. Young adult scores tended to cluster around a slope of 1.0 with a low standard error whereas data points for the other three age groups were more randomly distributed. A multivariate analysis in which both the standard error and the slope for each subject were used as dependent measures indicated that the four age groups differed significantly from one another when both of these measures were taken into account, $F(6,186) = 7.98$, $p < .001$ (using Roy's criterion). The discriminant function which according to Bartlett's Chi Square test maximally discriminates the four age groups, $\chi^2 = 43.07$, $df = 6$; $p < .001$, is drawn on the graph. The least overlap appears to be between the young adults and the other three age groups.

Thus inter-group comparisons of individual results yielded marked differences primarily between the young adults and the other three age groups. Young adults were both more consistent in their responding and more accurate in their time judgments.

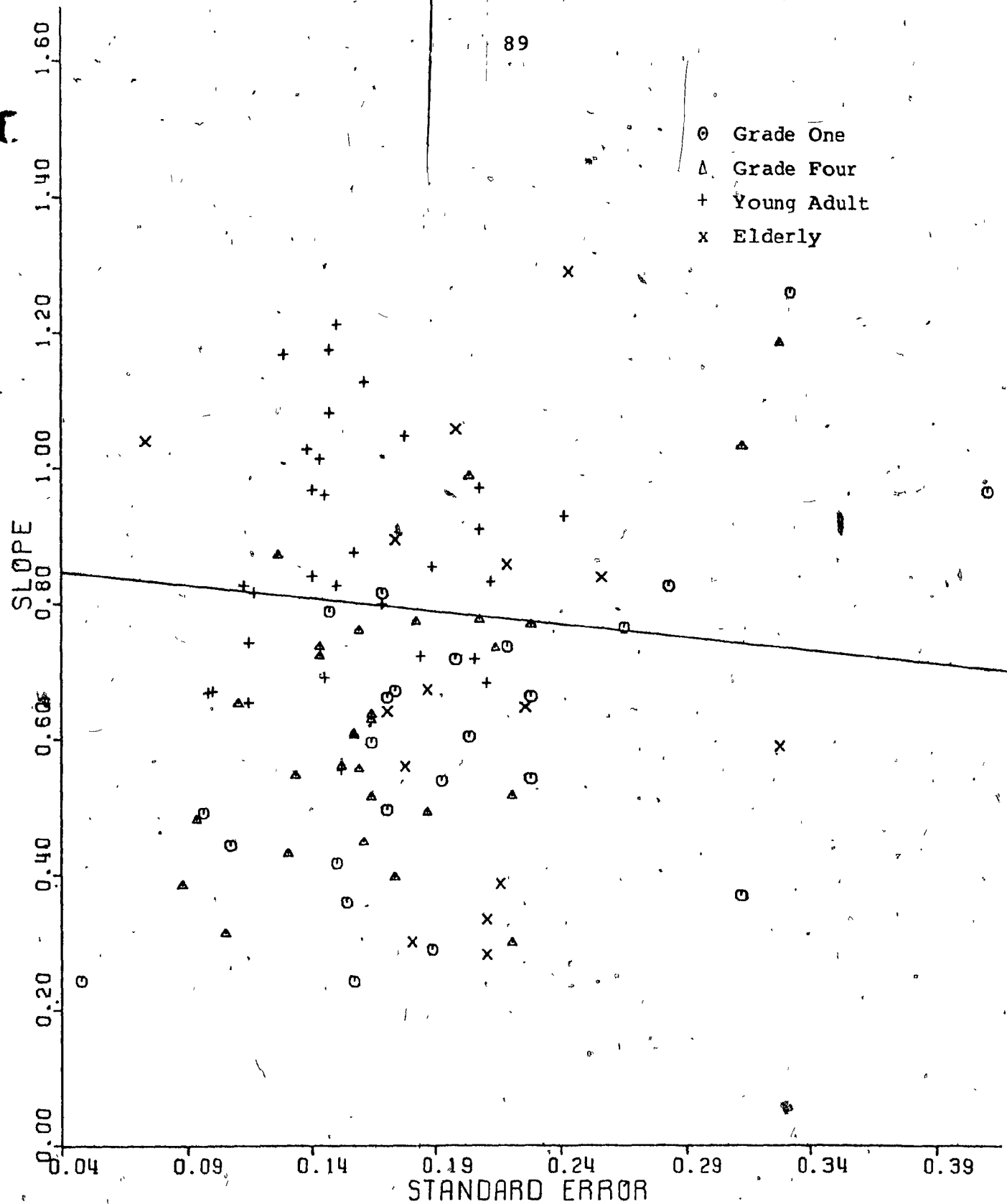


FIGURE 3. Individual standard error scores plotted against individual slopes for duration judgments of tones by four age groups.

EXPERIMENT 1B: Duration Estimation as a Function of
Stimulus Contextual Variables

Method

Subjects, Apparatus and Procedure

Immediately following Experiment 1A, all grade 1, grade 4, and young adult subjects took part in Experiment 1B. The apparatus and procedure remained the same with the exception that subjects were asked to use the bottom tape to estimate the duration of a sequence of tones rather than a single tone. At the end of the testing period, the young adult subjects were asked to answer a follow-up questionnaire (see Appendix E).

Stimuli

The audio tapes^o consisted of a series of 12 trials, each of which included a standard 262 Hz 12-sec pure tone paired with an interval which also always lasted 12 sec but which contained tone sequences that varied according to four different stimulus conditions and three different stimulus rates. In the first case, referred to as the "regular" condition, pure tones of the same frequency and intensity as the standard tone were repeated with equal timing and spacing. In the second condition, the pure tones were given a rhythm based on the tempo of the song Frère Jacques. This addition of variability in the length of tones and corresponding inter-stimulus

empty intervals, produced the "organized" condition. In the third condition, the pitch or tone frequency of the tones was changed. This was done by adding the melody of Frère Jacques to the rhythmic tones to produce a "familiar" condition. In the last condition representing "unfamiliarity", the notes of the Frère Jacques song were played in random order but maintaining the same rhythm (see Appendix F).

Each condition was presented in one of three speeds: slow, medium or fast; that is, the number of notes occurring in the 12-sec interval was either 16, 32 or 64. By combining the four different conditions with three different stimulus rates, 12 variable sequences, all of equal duration, were produced. The 12 trials were randomized in 10 different orders to provide 10 audio tapes. The format of each trial remained identical to that used in Experiment 1A, viz., knock, 2-sec of silence, standard 12-sec tone, 3 sec of silence, variable sequence presented in 12-sec interval.

Results

A 3x4x3 analysis of variance (age group x stimulus condition x stimulus rate) was applied to subjects' duration estimates of the tone sequences (measured in log cm). The last two factors represented repeated measures and accordingly conservative degrees of freedom were used in testing.

As shown in Table 6, there was a significant main effect for stimulus condition, $F(1,80) = 9.87$, $p < .01$, and stimulus rate, $F(1,80) = 19.21$, $p < .001$, but not for age group. Subjects estimated the durations of the "regular" and "organized" tone sequences to be approximately the same whereas "familiar" and "unfamiliar" conditions were judged as shorter. The "familiar" condition was estimated the shortest.

The significant main effect for stimulus rate was explained by the age group x stimulus rate interaction, $F(1,80) = 4.30$, $p < .05$. Tests of simple effects used to examine this interaction indicated that there were significant differences in the estimates given by grade 1 children, $F(2,80) = 8.00$, $p < .01$, and grade 4 children, $F(2,80) = 10.43$, $p < .01$, as a function of stimulus rate. Tukey tests revealed that for both groups of children, estimates given for the "slow" speed were significantly shorter than estimates of the "medium" and "fast" tone sequences (see Tables 7 and 8). Young adults showed no significant differences in responding as a consequence of stimulus rate.

TABLE 6
Three-Way Analysis of Variance of the Effects of Age
Group, Stimulus Condition and Stimulus Rate on
Duration Judgments of Tone Sequences

Source	SS	MS	df ^a	F
Age Group (G)	0.302	0.154	2	0.920
S (G)	13.249	0.164	80	
Stimulus Condition (R)	1.124	0.377	3 (1)	9.872**
RG	0.663	0.111	6 (2)	2.907
RS (G)	9.123	0.037	240 (80)	
Stimulus Rate (T)	1.390	0.695	2 (1)	19.209**
TG	0.626	0.154	4 (2)	4.302*
TS (G)	5.797	0.037	160 (80)	
RT	0.313	0.053	6 (1)	1.534
RTG	0.414	0.032	12 (2)	1.010
RTS (G)	16.294	0.032	480 (80)	

*p < .05

**p < .01

^aNote that conservative degrees of freedom were used in testing.

TABLE 7

Tukey Test Comparing Duration Judgments of Different
Stimulus Rates for Grade 1 Children

I - "SLOW" Speed
II - "MEDIUM" Speed
III - "FAST" Speed

	II	III
I	5.036**	6.558**
II		1.522

TABLE 8

Tukey Test Comparing Duration Judgments of Different
Stimulus Rates for Grade 4 Children

	II	III
I	5.407**	6.951**
II		1.545

**p < .01

df error = 80

Discussion

The principal finding obtained from this first study was that all age groups demonstrated the ability to take into account duration of simple auditory stimuli. Actual duration of pure tones was a much more potent predictor of subjects' time estimates than were the two extraneous variables trial and last response.

Age differences did emerge, however, on a number of measures. The performance of young adults clearly distinguished them from the other three age groups. They were better at discriminating tones of different lengths and were also more able to profit from information provided by the standard. Greater consistency also differentiated their temporal judgments from those of first graders and the elderly.

Although fourth graders (9 and 10-year-olds) were not able to be as accurate as the adults, they did demonstrate the ability to be as consistent in their responding. The elderly were least consistent and performed more poorly than any other age group. They had the greatest difficulty taking into account actual duration and were least successful at discriminating between different tone lengths. They also overestimated the 12-second interval relative to the standard more than other age groups indicating a strong negative time-order effect (Woodworth and Schlosberg, 1954). While it is not possible to provide any definitive explanation for these

results, it may be that their greater susceptibility to interfere on short-term memory tasks (e.g. Schonfield and Robertson, 1966; Talland, 1966) contributed to their poor performance. Thus far, the results of time estimation tasks with older subjects have been contradictory. One study indicated no significant differences between performance of adults and the elderly (Smythe and Goldstone, 1957); the other, demonstrated decrements similar to those described here (Goldstone, Boardman and Lhamon, 1958).

Of greater interest to the present investigator, was how the youngest children would perform. Six and 7-year-olds were not as consistent in their time judgments as older children and had somewhat greater difficulty distinguishing between tones of longer duration. Nevertheless, they did as well as older children in profiting from information provided by the standard. Their ability to "switch-in" to the temporal dimension of the task, as indicated by the percentage of variance accounted for by Time (63%), compared quite favourably to that of fourth graders (72%) and adults (84%). In addition, individual analyses revealed that for all 24 first graders, the actual duration of tones significantly predicted their temporal estimates. Only two subjects relied more heavily on an extraneous variable in making their judgments. These results were surprising in light of the fact that many authors have assumed that 6- and 7-year-olds are unable to estimate duration. This claim was based on

results from several developmental studies which demonstrated that 6 and 7-year-olds have the highest failure rate, the greatest intra-subject variability and are unable to profit from feedback on time estimation tasks (Goldstone, Boardman and Lhamon, 1958; Goldstone and Goldfarb, 1966; Smythe and Goldstone, 1957).

Crowder and Hohle (1970) have shown that children as young as 5 years can demonstrate the ability to estimate duration under certain specified conditions. Preschoolers were able to give accurate time judgments of short intervals when direct feedback regarding the direction and magnitude of errors was provided. In comparing their findings to former studies, these authors contended that in addition to explicit feedback, the children's success was in part attributable to the concreteness and relevancy of the task (i.e. children's game). The present study demonstrated that young children can take into account duration of arbitrary stimuli and that direct feedback is not a necessary prerequisite.

The second question considered in this first study was: Do duration estimates become confounded by other variables when the stimulus context is made more complex? Using tasks of differing complexity, Axel (1924) concluded that children's time judgments were more influenced by stimulus content than were estimates given by adults. The results of Experiment 1B confirm that certain structural properties of tone sequences did interfere with the temporal estimates of children.

When stimulus rate of tone sequences were varied, intervals filled with more stimuli were rated as longer by first and fourth graders alike. However, the children did not significantly discriminate between medium (32 tones) and fast (64 tones) rates although fast rates were estimated to be longer. Jones and MacLean (1966) observed a similar pattern with college students: the most rapid rates were not as influential in determining duration estimates as more moderate rates.

These findings also support Piaget's (1966, 1969) contention that speed is an important determinant of children's duration estimates. However, according to Piaget's schema, by the time children reach the stage of concrete operations, they have intuitively grasped the inverse relationship between time and speed and no longer confound the two variables. Yet the 9 and 10-year-olds in the present study were influenced by stimulus rate. These results seem to be more in line with Fraisse's (1963) more general claim that the subjective experience of time is a function of the number of changes perceived and does not rely on conservation of speed. The present study differs from Piagetian-type experiments in that children passively listened to tones. The dimensions of duration and speed may be more difficult to separate when presented auditorally rather than visually.

The adults' responses to the time questionnaire helped to clarify why alterations in speed failed to influence their

time judgments. Awareness of the purpose of the experiment seems to have been an important factor. Some subjects reported that it was difficult at times to refrain from using strategies and that they would suddenly become aware of paying attention to their breathing or some other covert cue such as humming to themselves. Others admitted to viewing the task as a test of their temporal estimation ability and many asked the experimenter "how well" they had done once the task was completed. A substantial number of adults reported that while faster speeds did "seem" longer, they "knew" that the effect was somewhat illusory and that "in reality" the duration had not changed. There was a high degree of between-subject variability in the data which suggests that some adults may have overcompensated as a consequence of such reasoning.

It could be that coding and storage processes effect the experience of duration but that at the time the temporal judgment is made, higher cognitive processes are used to compensate for certain distortions that could occur in coding and storing temporal information. This phenomenon may result regardless of whether or not subjects are informed as to the purpose of the task (Cohen, 1964).

Several authors (e.g. Loehlin, 1959; Mo, 1974; Schiff, 1970) have been tempted to make a distinction between temporal experience and temporal judgment. Mo (1974) has suggested that temporal experience may be effected by contextual

factors (i.e. stored duration length) and temporal judgments by nontemporal attributes (i.e. stored information). Verbal reports given by the subjects in this study also showed that some individuals seemed to have encoded and stored time as a separate component from the processing of nontemporal information. For instance, many subjects reported that they made a conscious effort to pay attention not only to the stimuli but also to the passage of time, otherwise they would have lost track of it. However, they could not specify what they did to mark the passage of time while listening to the tones.

Temporal judgments made by both children and adults were influenced by the more complex contextual variables examined. However, the results did not support the hypothesis that differences in levels of organization and differences in familiarity would influence the subjects' duration estimates. Rather, children and adults judged the "regular" and "organized" tone sequences as longer than both the "familiar" and "unfamiliar" melodies.

Regular and organized conditions did not yield the expected differences in duration estimates given by subjects. This may have been due to the fact that structural properties of the stimuli were not perceived as intended. Organization was introduced by grouping the regular occurring tones. However, adult subjects reported that the regular occurring pulsating tones at times appeared to follow a rhythmic pattern like the tick-tock of a clock.

Difficulties in defining stimulus contextual properties, also seemed to have effected the subjects' judgments of familiar and unfamiliar material. The unfamiliar melody (randomized notes) was intended to create an effect of novelty upon the subjects. However, this does not seem to have occurred in all cases. There were adults and children alike who, after the testing session, asked the name of the "unfamiliar" melody believing that they had heard it before. Thus, subjects' subjective perceptions of familiarity may have reduced the intended novelty effect of the unfamiliar condition. This might explain why familiar and unfamiliar tone sequences were not estimated to be significantly different from one another.

No particular hypothesis was postulated regarding the influence of melodious versus monotone sequences. Nevertheless, if Ornstein's (1969) results using familiar tasks and Avant and Lyman's (1975) findings regarding prerecognition of verbal material are combined, one might expect that familiarity reduces attention to a low level wherein less information is processed and thus duration experience shortened. This may explain why subjects estimated the melodies to be shorter than the rhythmic and regular pulsating tone sequences and why duration judgments of the familiar condition were the shortest. The storage size metaphor provides an alternative explanation for the present findings. The melodies differed from the two other sequences in that they were more highly organized (i.e. increased grouping with the aid

of pitch). According to Ornstein's (1969) hypothesis, more highly organized material is more easily chunked and coded and therefore has the effect of shortening temporal experience. A third explanation utilizes motivational constructs to explain why melodies were judged to be shorter than repetitious tone sequences. According to Loehlin's (1959) summary of findings, more interesting material is often perceived to be shorter in duration. This would be consistent with the adults' reports that the melodies came as a pleasant surprise in the midst of the monotone sequences.

The way in which attentional variables may have influenced subjects' estimates remains unclear. It has already been suggested that rapid identification of the more familiar material may have resulted in a decrease in amount of information processed thus shortening subjects' estimates. However, many adults claimed that they were more attentive to the melodious intervals. Some authors (e.g. Neisser, 1967; Lindsay and Norman, 1972) have suggested that selective attention increases the amount of information processed and consequently lengthens duration experience. Yet if subjects were bored during the repetitious intervals, time experience may also have lengthened as a function of mediating thoughts and fantasies or paying attention to the passage of time (e.g. Woodrow, 1951). It seems that attention has been a confounding variable in this experiment. It could be that the passivity involved in listening to tones favoured the

processing of other information. Cognitive tasks requiring subjects to be more active should allow for better control of attentional processes.

In summary, the results of Experiment 1B demonstrated that temporal judgments given by both adults and children are influenced by higher-order stimulus contextual variables. The performance of first and fourth graders demonstrated that they were affected by stimulus rate, although adults were not. It was suggested that under certain circumstances, adults use reasoning and logic to "correct" their subjective experience of duration and that different cognitive mechanisms may be involved in temporal experience as opposed to temporal judgment.

Temporal estimates of adults and children were influenced by melodious tone sequences in contrast to sequences involving pure tones. A number of variables including subjects' awareness of task, memory, attention and motivation seemed to have influenced the findings obtained. These variables may have affected children and adults in different ways. The young children possessed only a rudimentary understanding of duration and so may have been affected by these variables in a manner different from adults. But because children are less conscious of the impact of these factors on their experience or judgment of duration, it is hard to get a verbal report of their subjective impressions. Another approach would be to assess their perceptions in more

varied contexts and relate these to the cognitive and memory skills they possess.

EXPERIMENT 2

The present series of investigations focussed exclusively on the young child's perception of duration. The cross-sectional results obtained in Experiment 1A demonstrated that children as young as 6 and 7 years are able to estimate the duration of pure tones using a simplified response measure. This finding made it possible to begin to explore several new issues: Can younger children estimate duration? Can children judge the duration of other stimuli which convey a lapse of time? What cognitive and behavioral factors contribute to a more adult-like perception of time among young children?

A major concern of previous investigators has been the age at which children become capable of estimating duration. Unfortunately, methodological difficulties have seriously impeded research involving very young children. Most psychophysical studies that have used 6 and 7-year-old subjects (e.g., Goldstone, Boardman and Lhamon, 1958; Goldstone and Goldfarb, 1966; Symthe and Goldstone, 1957) have concluded that children are unable to make accurate and consistent time judgments before the age of 8. Thus an initial question for the present investigator was whether or not the above findings would also be obtained for a younger sample of children. Throughout Experiment 2, two groups of children were studied: kindergarteners (age 5 and 6) and first graders (age 6 and 7). In the first phase of the study, they were given the

task of estimating tones so that the performance of 5 and 6-year-olds could be assessed.

Contemporary research has also neglected to examine the young child's ability to estimate more naturalistic and relevant stimuli such as familiar activities. Due to concerns regarding experimental control, those who have used the psychophysical approach to examine time perception in children have been hesitant to go beyond using arbitrary stimuli and very short durations. Yet whether or not the results of these studies are applicable to the child's memory for duration of more familiar events remains an unanswered question. The research documenting the development of time concepts suggests that before the young child is able to identify conventional time units, he uses specific, familiar activities to denote duration (e.g. Ames, 1946). It is possible then, that prior to acquiring clocktime knowledge, young children can estimate the duration of such relevant stimuli. On the other hand, concrete events may simply be an available unit of time for young children, though inaccurately used. The second phase of this study examined precisely this issue by examining children's time judgments of familiar school routines.

Since the age frame between 5 and 7 years encompasses children who possess temporal skills ranging from adult-like to undeveloped, one can question the source of these differences. What are the perceptual and cognitive processes that enable children to estimate duration? In the third and last

phase of this study, kindergarten and first graders were tested on a number of cognitive and behavioral skills. These measures were then evaluated in terms of their contribution to the children's performance in estimating the duration of tones and routines.

Tones and routines were estimated using a methodology that differed somewhat from that employed in Experiment 1. Rather than presenting subjects with a standard interval prior to each trial, a range was introduced once at the outset of the task to identify the stimulus continuum. Presenting a range saves time and reduces the subject's tendency to avoid the end portions of the scale (Stevens and Gallanter, 1957). Thus, the technique may aid the subject to be more discriminant in his time judgments, however, it also deprives him of information that can be used for comparison purposes on each trial. If young children do rely on information provided by a standard, then they may perform more poorly with this method. On the other hand, if standards for tones and routines have been effectively internalized, presenting a range should make little difference to them. By varying the methodology, the issue of standards could be addressed and the relative merits of these two techniques examined.

In Experiment 2A involving estimation of tones, a further methodological modification was made. Instead of equally spacing the tone durations (i.e., 3, 6, 9 sec . . .), stimuli were logarithmically spaced such that the width separating

the tones increased as a function of stimulus duration. Psychophysical studies of duration with adults (e.g. Gregg, 1951; Ross and Katchmer, 1951) have demonstrated that psychological magnitude of apparent duration is a slightly accelerating function of physical duration. This may explain why the children in Experiment 1A, did not discriminate well between longer tones. When stimuli are unequally spaced, the longer durations become more distinguishable and the slope more linear (Stevens and Gallanter, 1957).

Based on the findings from Experiment 1A and given the alterations in method outlined above, it was hypothesized that kindergarten children as well as first graders would be able to distinguish between tones of different duration. It was expected that should differences between the age groups arise, results would parallel those obtained by other investigators (e.g. Fraisse and Orsini, 1958; Smythe and Goldstone, 1957; Goldstone and Goldfarb, 1966) in that younger children would have greater difficulty being consistent. Sex differences were also examined, though the contribution of this variable has not been substantiated (e.g. Axel, 1924; Gilliland and Humphreys, 1943; Goldstone and Goldfarb, 1966; Smythe and Goldstone, 1957).

In experiment 2B, children estimated the duration of several familiar school routines that fitted four duration categories: short, medium, long and extra-long. It was hypothesized that both kindergarteners and first graders

would have greater difficulty discriminating duration of routines than of tones. The task was, in many ways, more demanding. Duration judgments of routines were retrospective thus relying more heavily on memory. Furthermore, cognitive and verbal skills may have been necessary for the child to be able to conceptualize the routines in question. It was also expected that other temporal skills such as knowledge of clock-time would be useful for this task.

In the discussion regarding Experiment 1, it was suggested that motivational variables may influence judgments of duration even when more neutral stimuli are used. It was expected that the children's estimations of familiar school routines would be highly affected by the children's subjective feelings regarding these activities. Thus two motivational variables were systematically studied: task difficulty and pleasantness of task.

Investigators who have sought to examine the influence that motivational factors may have on time judgments made by young children are few indeed. A single exception, has been the work of Fraisse (1963). His theoretical framework is based on the central premise that duration judgments are determined by the number of changes perceived. He has interpreted the results of Piaget's (1969) experiments in terms of effort by claiming that when the amount of effort required is increased, the number of changes perceived are greater thus lengthening the apparent duration.

Doob (1971), has thoroughly reviewed the adult literature concerning the effects of motivational factors on time perception. He also concluded that task difficulty weakens "drive" and thus has the effect of decelerating the subjective experience of duration.

Presently, there is little empirical work that deals directly with the relationship between task pleasantness and duration experience. The present investigator was unable to locate any relevant studies conducted with children. Although definitions of this dimension have varied widely, some of the more rigorous studies with adults have suggested that increased satisfaction has the effect of shortening time experience (e.g. Goodchilds, Roby and Ise, 1969; Loehlin, 1959). This phenomenon has been explained in terms of a lack of attention to the passage of time when one is fully engrossed in a pleasant activity.

Fraisse (1963) has noted, however, that when duration judgments are made in retrospect, pleasant events may become more salient and thus temporal experience may lengthen. Few empirical studies have investigated the relationship between task pleasantness and durations in retrospect and so far results remain inconsistent. Schiff (1970) reported that although the pleasantness of films viewed did not interact with the immediate/retrospective factor, subjects did report that the more interesting film "seemed" longer when the judgment was delayed. Schiff suggested that contradictory findings

may be due to the fact that retrospective judgments of duration are influenced by whether or not adults have reported the "raw" phenomenal temporal experience or whether they have used objective standards to "correct" their experience. His results indicated that it was the "corrected" aspect of experience rather than the "raw" aspect which was stored.

In the present study, children subjectively evaluated activities by assigning them to two categories: "fun" or "no fun" and "hard" or "easy". The effect of these variables on lengthening or shortening duration estimates of activities was examined. A further question concerned how salient these affective qualities might be. Would motivational variables be more potent predictors of temporal estimates than duration itself?

In Experiment 2C, the children were assessed using a number of behavioral and cognitive measures in an effort to determine the kinds of abilities and skills that make it possible for young children to be precise in their estimates of duration. Aside from the age factor already discussed, these measures included indices of verbal and non-verbal ability, memory capacity, academic performance, clocktime knowledge, temporal sequencing ability and temporal behavioral skills. These measures were chosen primarily on the basis of current theoretical speculation regarding the processes underlying perception of duration.

Verbal and non-verbal ability could potentially contribute

to time estimations in one of two ways. It was assumed that there would be some relationship between verbal skills and performance on the time tasks because success was partially determined by ability to understand instructions and conceptualize routines. Of particular interest, however, was the unresolved issue of possible lateralization of function. Some writers (e.g. Ornstein, 1972) have suggested that the right (non-dominant) hemisphere may be used for processing temporal duration. If this is the case, then non-verbal ability rather than verbal ability may be a more influential variable in predicting precision on temporal estimation tasks.

Proponents of the information processing model (e.g. Block, 1974; Ornstein, 1969; Vroon, 1970) have contended that temporal experience is directly dependent upon memory process and that perception of duration is determined by the amount of "space" taken to store information. If such is the case, then it might be expected that children with poor memory ability would also have difficulty estimating duration. As a test of this hypothesis, three different memory tasks were employed to yield measures of auditory memory capacity. These tests differed in stimulus content and the kinds of cognitive demands made on the child. The first involved the use of non-verbal stimuli; the second demanded recall of verbal material; and the third encompassed skills of verbal comprehension as well as the ability to retain information while carrying out instrumental tasks. More than one index of memory capacity

was considered necessary because of the following unanswered questions: First, the relationship between performance on one type of memory task and performance on another was unknown. Second, which type of memory task, if any, best taps abilities that are also important in making duration judgments was still an open question.

Very little is known about the relationship between temporal abilities and the cognitive skills which are part of academic functioning. All teachers had (independently of the study) tested their students individually on a variety of readiness skills and had divided their classes into three or four groups. The experimenter made use of these rankings as a general index of academic performance.

Each child's knowledge of clocktime was assessed to determine whether or not ability to read the clock would improve the consistency and accuracy of subjective time estimates. It was expected that this measure would be a more potent predictor of performance on routines than on tones.

It is also unclear if or how different types of temporal skills are related to one another (Bateman, 1968). One dimension of time which has received considerable attention from researchers and clinicians is temporal sequencing ability (e.g. Kahn and Birch, 1968; Rudnick and Sterrit, 1967). This is perhaps because temporal order is so fundamental to spoken and written language. In the present study, ability to order events in time was assessed using a picture arrangement task

in an effort to explore the relationship between temporal sequencing ability and the ability to judge duration.

Lastly, temporal behavioral skills of kindergarten children and first graders were assessed by their respective classroom teachers. The results of a pilot questionnaire study and discussions with elementary school teachers suggested that children manifest temporal difficulties in the classroom through a variety of behaviors. Some of the target behaviors noted by teachers included: difficulties being punctual, problems allotting time for tasks, difficulties organizing work effectively and inability to follow school routines. Temporal problems of this sort were expected to manifest themselves more in the routine estimations than in tone estimations.

Method

Subjects

Thirty kindergarten children (17 male, 13 female) with a mean age of 5 years, 10 months and 32 grade 1 children (16 male, 16 female) with a mean age 6 years, 11 months, took part in the second study. The children were all recruited from Lorne School, a public elementary school located in Pointe St. Charles which is a lower class English-speaking district of Montreal. The kindergarten children attended school for half a day, either morning or afternoon. The classroom teacher and schedule of activities was identical for the two kindergarten classes. The grade 1 children were randomly selected from one of two homeroom classes. These students were streamed at the outset of the school year into either class 1 or class 2 (the "brighter" group) based on their academic performance the previous year. Seventeen children from class 1 (9 male, 8 female) and 15 children from class 2 (7 male, 8 female) participated in the study.

Apparatus

The apparatus was identical to that employed in Experiment 1. In the present study, however, no standard was given. Thus subjects were told to ignore the top line and to use the bottom

tape only in making their temporal judgments.

Procedure

The present study was carried out in three phases. Children were seen individually during regular school hours and testing was divided into three 25-min sessions spaced approximately one week apart. During the first session, a battery of tests was administered; in the second session, the child was asked to estimate the duration of tones; and in the final session, the child judged the duration of familiar school routines and sorted them as to "fun" and "difficulty". For the sake of clarity, the method and results for each phase of the study will be treated separately in the following order:

Experiment 2A: Children's Duration Estimates of Tones

Experiment 2B: Children's Duration Estimates and Subjective Ratings of Routines

Experiment 2C: Cognitive and Behavioral Measures as Predictors of Children's "Precision" on Duration Tasks.

EXPERIMENT 2A: Children's Duration Estimates of Tones

MethodStimuli

As in Experiment 1, a computer was used to generate tones of identical frequency (262 Hz) and variable duration. "Anchor" tones of two durations were used to define the range of the stimulus continuum. A 1-sec tone was used to represent the "shortest" possible line that could be made with the bottom tape (approximately 3.0 cm) and a 30-sec tone was used to designate the "longest" line (96 cm). The presentation order of these two tones was counterbalanced.

Subjects were presented with test tones that were 2, 5, 11, 17 and 25 sec long. Tones were randomized within two blocks of five such that each variable tone was presented twice, once in each block. There were five different orders of presentation for the 10 trials. A single trial consisted of a ready signal, 2 sec of silence, and then the variable tone followed by 5 sec of silence. Again the tones were put on tape and both the child and tester listened to them through earphones at a volume of 7-80 db.

Procedure

The procedure was similar to that adopted in Experiment 1A. The experimenter began the session by introducing the

child to the "time machine" and allowing him to explore it by pulling out the bottom tape and making lines of different lengths. Then, to ensure that the child would have no difficulty comprehending later instructions, the tester manipulated the tape and also asked the child to do so in order to assess his knowledge of such terms as "short", "long", "medium", "shortest", "longest". The tones used to define the stimulus range were then introduced:

We're going to listen to the sound and then we're going to make a line with the time machine that tells exactly how long the sound is.

The first is the shortest sound. Right before the sound comes you'll hear a 'beep-beep' and that means: Are you ready?--because the sound is coming. So let's begin. Listen carefully. This is the shortest sound (demonstration).

Now, can you make me a line that tells how long that sound lasted for? (child pulls out tape). Good. It was the shortest sound and so we make the shortest line.

Now we are going to listen to the longest sound. Are you ready? (demonstration). Can you make me a line that tells me how long that sound was? (child pulls out tape). Very good. That was the longest sound so we make the longest line.

The 10 test trials were given immediately following introduction to the anchor tones. To encourage full use of the range of the apparatus and to prompt the child to use fine demonstrations in making his judgments the following instructions were used:

There are lots more sounds on my taperecorder that I want you to measure by yourself. The sounds are all different lengths. Some of them are this long (demonstration of a short line), some this long

(demonstration of a long line), this long or this long (experimenter makes lines spanning full range of slit)--all different sizes. You are going to have to listen very carefully to the sound because you have to make the line exactly how long the sound is. Do you understand? Good. So let me put these earphones on you. They'll help you to concentrate and hear the sounds better.

The child was instructed to remain still and quiet while the taperecorder was on. Following each trial, the taperecorder was turned off; then a signal was given the child to pull out the line, his response was recorded by the tester and the tape was returned to starting point. For the first few trials, the child was given the following prompt: "Can you make me a line that tells exactly how long the sound lasted for?"

Testing proceeded without a break until all 10 test trials were completed. The experimenter observed the child's behavior to ensure that no overt strategies such as counting, humming or tapping were used to pace the interval.

Results

Tone Judgments

Group and individual regression analyses were performed on the log transformed data for the two age groups using the same reasoning outlined in Experiment 1A. The only way in which the present analyses differed was that sex was included as an additional predictor variable.

Group Analyses

The results of the kindergarten and grade 1 group regression analyses are shown in Table 9. Clocktime duration was the best single predictor of the children's temporal judgments of variable tones. The Time variable accounted for 54% of the overall variance in responding of the kindergarten children and 62% of the variance in responses given by the grade 1 group. In both cases, the F value for Time taken at the last step was significant at the .001 level.

Table 10 depicts the best fitting regression model for each age group. More than one independent variable best predicted the children's responses. Last R was a significant predictor for kindergarten, $F(1,295) = 20.92$, $p < .01$, and grade 1 children $F(1,315) = 11.94$, $p < .01$. The positive correlation coefficient suggests the operation of sequential dependencies. The children's estimates on a particular trial tended to vary in the same direction as estimates given on the

TABLE 9

Group Regression Analyses for Duration Judgments of Tones
by Kindergarten and Grade 1 Children

Age Group	Variable	Simple R	Multiple R	R Square	F to Enter	Usefulness
Kindergarten N=30	Time	0.735	0.735	0.541	387.916***	7.122
	Last R	0.131	0.760	0.578	20.918**	0.353
	Trial	0.143	0.760	0.578	0.173	0.003
	Sex	0.046	0.761	0.580	1.198	0.020
Grade 1 N=32	Time	0.789	0.789	0.622	547.414***	7.644
	Last R	-0.013	0.793	0.629	11.935**	0.164
	Trial	0.103	0.799	0.639	7.411**	0.099
	Sex	0.029	0.800	0.641	1.707	0.023

***p < .001

**p < .01

TABLE 10

Best Fitting Model Derived from Group Regression Analyses for Duration
Judgments of Tones by Kindergarten and Grade 1 Children

Age Group	REGRESSION COEFFICIENT			Constant (b)	Multiple R	Se	F ^b
	Time (b ₁) ^a	Additional Predictor (b ₂)	Additional Predictor (b ₃)				
Kindergarten	0.789±.082	0.806 (Last R)	-	1.410	0.760	0.543	203.207***
Grade 1	0.739±.063°	0.749 (Last R)	0.775 (Trial)	1.882	0.799	0.448	186.287***

***p < .001

^aThe quantity following the (+) or (-) is the 95% confidence limit.

^bCumulative F for best fitting model.

previous trial. For first graders, Trial was a second additional predictor $F(1,315) = 7.41, p < .01$. The negative correlation coefficient between trial and duration estimate indicated that as the grade 1 children proceeded through the task, their duration estimates tended to become shorter. Sex was not a significant predictor of temporal estimates for either age group.

As in Experiment 1A, the usefulness values and R^2 change values were determined for the independent measures in order to examine their relative importance as predictor variables (see Table 9). Time accounted for most of the variance and had the highest usefulness value. While Last R and Trial were significant, this was partially due to the large sample size. Last R accounted for only 4% additional variance in the case of the kindergarten group and less than 1% additional variance in responding of first graders. Similarly, the R^2 change for Trial in the case of first graders was only 1%. Thus the major finding from the regression analyses was that actual duration of tones was the key determinant of children's estimates. Sex was not a useful predictor. Trial and Last R occasionally did reach significance but these two predictors proved to be of minimal relative importance.

A group standard error of .57 was obtained for the kindergarten sample as opposed to .46 for the grade 1 group. These scores are rather high indicating that children, in general, had difficulty being consistent in their responding.

Slopes for the two age groups are given in Table 10. Those taken from the first step (i.e. Time) were: kindergarten, $b = .79$; grade 1, $b = .74$). As in Experiment 1A, the slope was used as an index of proportionality of judgment. The slopes were close to an ideal value of 1.0 indicating that as the duration of tones increased, the estimates given by the children also increased at approximately the same magnitude.

The children's ability to distinguish between tones of variable duration and possible practice effects were further examined by performing separate analyses of variance and Newman Keuls comparison tests for the two age groups. Here the dependent measure was again the log-transformed centimeter tape setting responses of the subject.

Table 11 provides a summary of the results of the two-way analyses of variance (block x tone length) performed on the kindergarten data. Conservative degrees of freedom were used to test all within-subject sources. There was a significant main effect for block, $F(1,29) = 5.60$, $p < .05$, indicating that the children's estimates in the second block of trials were somewhat longer than those given in the first block. There was also a main effect for tone length, $F(1,29) = 130.59$, $p < .001$. In Figure 4, mean tape setting response (log cm) is plotted against duration of variable tone (log sec). As illustrated, the kindergarten children increased their estimates as the duration of the variable tones

TABLE 11

Two-Way Analysis of Variance of the Effects of Tone Length
and Block on Duration Judgments by Kindergarten Children

Source	SS	MS	df ^a	F
B (Block)	1.217	1.217	1	5.598*
SB	6.303	.217	29	
T (Tone Length)	125.118	31.279	4	130.587**
ST	27.785	.240	116(29)	
BT	2.044	.511	4(1)	3.982
SBT	14.891	.128	116(29)	

*p < .05

**p < .01

^aNote that conservative degrees of freedom were used in testing.

lengthened. However, examination of this figure indicated that the children did not utilize the range (i.e. 3.0 cm for 1-sec tone, 96 cm for 30-sec tone) set by the experimenter. Of particular note was the fact that duration judgments of the shorter tones (2- , 5- , 11-sec) were considerably longer than what might have been expected had the children utilized information provided by the anchor tones.

The Newman-Keuls multiple comparison test was used to examine which tone durations were perceived as significantly different from one another. A summary table of the results of this analysis may be found in Appendix G. The analysis indicated that the kindergarten children were able to distinguish between the tones on the basis of duration. Longer variable tones were more difficult to discriminate than shorter ones, however, all tone comparisons were significant ($p < .05-.01$).

A three-way analysis of variance (classroom group x block tone length) was applied to estimates given by grade 1 children. As shown in Table 12, when conservative degrees of freedom were used, there was once again a significant main effect for block, $F(1,30) = 4.88$, $p < .05$, and a significant main effect for tone length, $F(1,30) = 163.31$, $p < .001$. The grade 1 children also judged tones in the second block to be significantly longer than those in the first. Temporal judgments made by the two classroom groups were not significantly different from one another.

TABLE 12

Three-Way Analysis of Variance of the Effects of Tone
Length, Block and Classroom Group on Duration
Judgments by Grade 1 Children

Source	SS	MS	df ^a	F
G (Classroom Group)	0.005	0.005	1	0.006
S(G)	25.881	0.863	30	
R (Block)	0.456	0.456	1	4.878*
RG	0.002	0.002	1	0.016
RS (G)	2.804	0.093	30	
T (Tone Length)	121.484	30.371	4(1)	163.309***
TG	0.632	0.158	4(1)	0.850
TS (G)	22.317	0.186	120(30)	
RT	0.727	0.182	4(1)	1.574
RTG	0.503	0.126	4(1)	1.089
RTS (G)	13.852	0.115	120(30)	

*p < .05

***p < .001

^aNote that conservative degrees of freedom were used in testing.

Figure 4 depicts the mean judgments of duration given by the grade 1 sample for each of the variable tones. The children's estimates increased in accordance with increases in duration. Duration judgments given for the shorter tones indicated that first graders also responded without making use of the stimulus range. The Newman-Keuls comparison test (see Appendix G) demonstrated that all tone comparisons were significant ($p < .01$) with the exception of the 17- and 25-sec tone comparison which was marginally significant at the .05 level.

To summarize, the group analyses demonstrated that kindergarten children as well as first graders were able to distinguish between tones of variable duration. For both groups, longer tones were more difficult to discriminate from one another than shorter ones. Though the children had some difficulty being consistent in their estimates, their duration judgments were proportional. This occurred despite the fact that neither sample of children took into account information regarding the stimulus range.

Inter-Group Comparison of Individual Results

Regression analyses were performed on the 10 temporal estimates given by each individual child. These analyses were identical in form to the group analyses, however, sex was not included as a dependent measure.

Appendix H provides a summary of the best fitting model

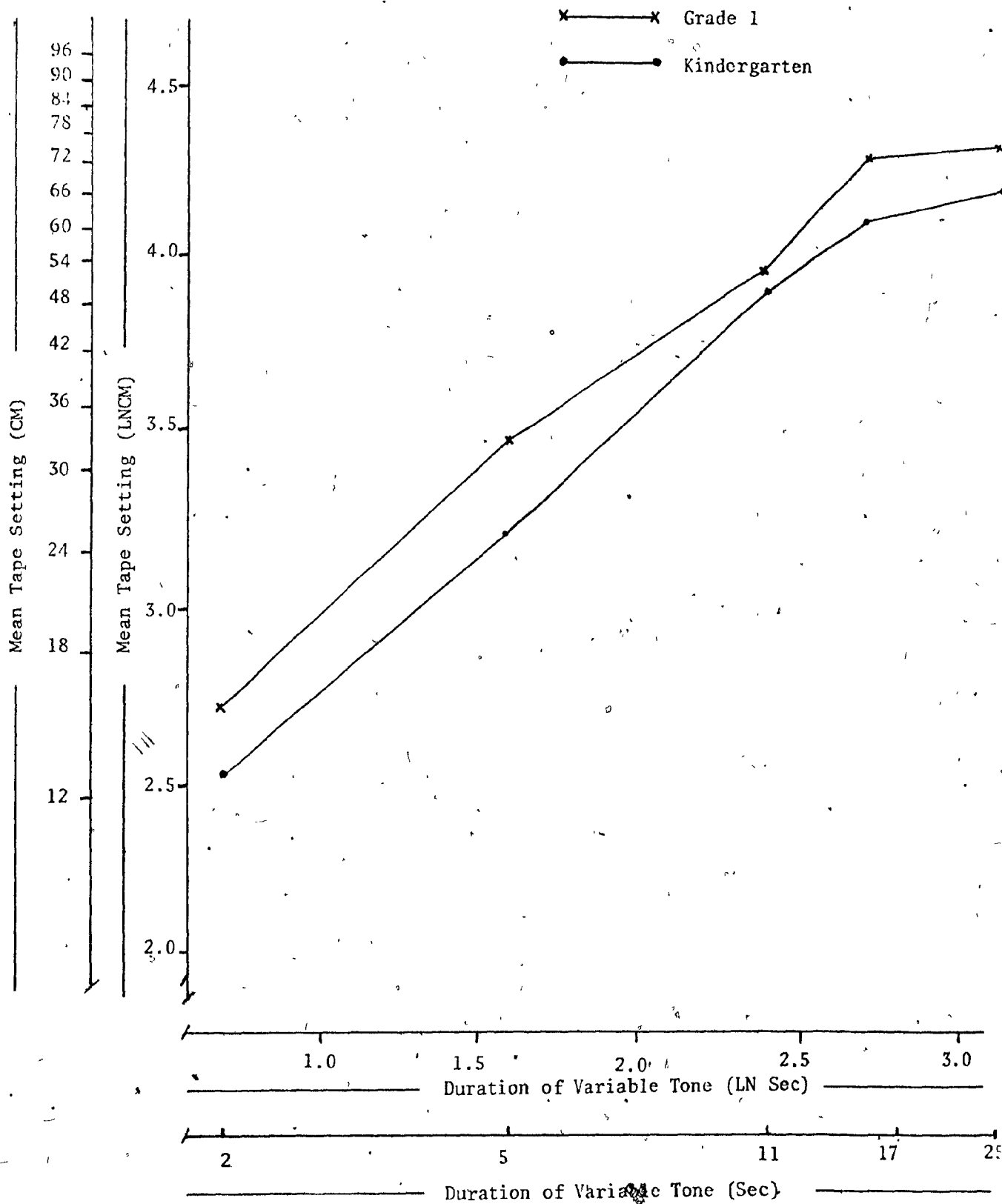


FIGURE 4. Mean judgments of duration of variable tones for kindergarten and Grade 1 children.

for each of the 62 subjects. Again a conservative cut-off, $F(1,6) = 13.70$, $p < .01$, was used to test the tolerance F at the last step for each independent variable. There was no subject in either the kindergarten or grade 1 group for whom Trial or Last R acted as a significant additional predictor. However, examining each child's data individually revealed that all subjects did not take duration into account when making their judgments. For two of the 30 kindergarten children (subjects 19 and 23) and one grade 1 child (subject 9), Time was not a significant predictor variable (criterion level = $F(1,8) = 5.32$, $p = .05$). In fact, none of the independent measures predicted the responses of these children.

Standard error scores were calculated for each individual subject and the mean standard error score was determined for each age group. These scores were somewhat lower than those taken from the first step of the group regression analyses (Kindergarten $Se = .36$; Grade 1, $Se = .32$). In the case of both age groups, however, the individual scores covered a considerable range (Kindergarten: .13 to .74; Grade one: .12 to .87). Thus, there was a good deal of between-subject variability in the children's ability to be consistent.

Table 13 provides a summary of the one-way analysis of variance performed on the individual standard error scores. There were no significant differences between the two age groups in their ability to respond consistently, $F(1,60) =$

.80; $p > .05$, and the standard deviations of these scores for the two age groups were identical ($SD = .16$).

A one-way analysis of variance was also applied to the slopes taken from the individual regression analyses in order to examine possible age group differences. Again, the standard deviations of the slopes was high (kindergarten, $SD = .25$; Grade 1, $SD = .22$) indicating large individual differences. As shown in Table 14, there were no significant differences between the two age groups in the slopes of their duration judgments, $F(1,60) = .37$, $p > .05$.

Thus, kindergarten children and first graders did not differ from one another either in consistency or their ability to make judgments proportional. However, individual differences were considerable. It is important to note the inter-individual variations in slope and standard error scores as these two measures were used as dependent variables in the third phase of this study.

TABLE 13

One-Way Analysis of Variance of the Effects of Age Group
on Standard Error Scores of Duration Judgments of Tones

Source	SS	MS	df	F
G (Age Group)	0.020	0.020	1	0.801 n.s.
S (G)	1.525	0.025	60	

TABLE 14

One-Way Analysis of Variance of the Effects of Age Group
on Slopes of Duration Judgments of Tones

Source	SS	MS	df	F
G (Age Group)	0.020	0.020	1	0.370 n.s.
S (G)	3.285	0.055	60	

EXPERIMENT 2B: Children's Duration Estimates and
Subjective Ratings of Routines

Method

Stimulus Materials

Sixteen pictures depicting familiar school routines were drawn in black ink on 15x10 cm white index cards and covered with plastic. One set of eight was made for the kindergarten group and a different set for the grade 1 group. The activities in each set covered four different durations: short, medium, long, and extra-long.

The activities chosen for the kindergarten group and their respective durations were as follows:

- (1) Children hanging up their coats in the cloakroom (1 min).
- (2) Children sitting in a circle on the floor waiting for the teacher to start morning exercises (1 min).
- (3) Children seated on the floor and on benches in a line waiting outside the classroom for the teacher to arrive (5 min).
- (4) Children getting dressed and ready to go home (5 min).
- (5) Children playing with special toys made available to them only at "playtime" (15 min).
- (6) French class (15 min).
- (7) Gym (30 min).
- (8) Children doing "workjobs" in groups of small tables (30 min).

For the grade one children, the following familiar routines were illustrated. Note that the durations were somewhat longer, however, they still fitted four distinct duration categories.

- (1) Children hanging up their coats and putting away their books in cloakroom (2 min).
- (2) Children standing in line waiting outside the classroom for the teacher to allow them in (2 min).
- (3) Recess (10 min).
- (4) Children cleaning up the classroom at the end of the day and getting dressed and ready to leave (10 min).
- (5) Library period (20 min).
- (6) French class (20 min).
- (7) Gym class (20 min).
- (8) Lunchtime: defined as amount of time between dismissal bell and arrival back at school (60 min).

Samples of the picture cards used are provided in Appendix I. They were carefully drawn, depicting important features of the classroom and activity portrayed so that the children would have little difficulty identifying them.

In order to choose appropriate activities, the experimenter observed the daily activities of each class on several occasions. Only activities which could meet all of the following criteria were selected.

- (a) Familiarity: The activity had to be part of the regular school routine.

- (b) Temporal distinctiveness: Only activities having a clear beginning and end were utilized.
- (c) Duration constancy: Only activities for which the time allotted had not changed during the course of the year were used.
- (d) Uniformity of routine: The routines had to be uniform in content and duration across classes.
- (e) Active vs. passive: The routines for each age group included some activities in which the child was relatively passive and others in which he was active.

Procedure

The subject was seated at a desk across from the experimenter and the session began by introducing the child to the picture cards:

I've got some very special pictures to show you today. They're all pictures of things that you do in school. I'm going to show them to you one at a time and see if you can guess what they are.

The experimenter went through the picture cards with the child until he was able to identify all eight activities accurately.

Next the child was shown that the apparatus could be used to judge activities as well as sounds. The experimenter proceeded with the following instructions and trial exercises:

Now I'm going to take out my time machine. Do you remember how last time you made lines to let me know how long sounds lasted for? We can also use the

time machine to measure how long it takes to do things.

I am going to sing and then I'm going to clap. You listen carefully because when I'm done I'm going to ask you which took longer. Are you ready? This is clapping (Experimenter claps for 3 sec). This is singing (Experimenter sings for 8 sec). Which took longer? Good. Let's make some lines with the bottom tape to show how long it took to clap, then how long it took to sing.

The same procedure was followed comparing different activities (e.g. hopping vs. walking) and two instances of the same activity (e.g. clapping for 10 sec vs. clapping for 4 sec) until it was clear that the child was cuing into the temporal dimension of the task. The average child received 2 or 3 test trials.

Immediately following these exercises, the child was presented with the picture cards of the familiar school routines, one at a time, and asked to use the bottom tape to estimate the duration. A range was set by explaining to the child that the "longest" line represented the amount of time spent at school in a day. Note that for the kindergarten children this meant half a day whereas for the grade one children it meant a full day. Prior to each trial, the child was given the following prompt:

Do you remember what this is a picture of? Good. Can you make me a line that tells me how long it takes to...? Remember, think first. Once you've decided, pull out the line right away. Make the line exactly how long it takes.

After each trial the experimenter recorded the centimeter tape

recording and the child was told to return the tape to starting point.

There were a total of 16 trials per subject. The activities were randomized into two blocks of 8, each activity being presented once in a block, so that practice effects could be easily examined. There were 5 different orders of presentation and each child was randomly assigned to one of these.

Following the temporal estimation task, the children sorted the activities according to two subjective dimensions: fun and difficulty. The child was given the 8 picture cards and told:

Now we're going to make two piles with these pictures. Over here I want you to put the pictures of the things that you find fun to do and over here we'll make a pile of the things that aren't so much fun. Look at the picture carefully, tell me what it is and then put it in the right pile.

The identical procedure was followed in sorting the activities as to whether they were "hard" or "easy".

Results

Group regression analyses were performed on the duration estimates of familiar school routines given by the kindergarten and grade 1 children. Five independent measures: Time, Last R, Trial, Fun, and Difficulty were explored as possible predictors of the children's log transformed tape setting responses. Analyses of variance were also carried out in an effort to examine whether or not and if so, precisely how the children's temporal judgments were influenced by practice, duration of activity, activity type, and in the case of the grade one sample, classroom group. The Newman-Keuls and Scheffé multiple comparison tests were used to determine how well the children were able to distinguish activities of different durations. The group results for the two age groups will be examined separately. Subsequently, inter-group comparisons of individual results will be considered and results of this study will be compared with those of Experiment 2A.

Group Analyses: Kindergarten

Tables 15 and 16 summarize the results of the group regression analysis for the kindergarten children. As shown in Table 15, four of the five independent measures proved to be predictive of the children's duration estimates. The percentage of variance accounted for by each of these variables, however, including Time, was rather low. Time accounted for

TABLE 15

Group Regression Analysis for Duration Judgments of Routines
by Kindergarten Children (all predictors included)

N=30

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
Time	0.290	0.290	0.084	31.696**	1.210
Last R	0.220	0.365	0.133	34.902**	1.261
Difficulty	-0.185	0.393	0.154	12.023**	0.424
Trial	-0.035	0.408	0.166	6.968**	0.242
Fun	-0.090	0.409	0.167	0.472n.s.	0.016

TABLE 16

Group Regression Analysis for Duration Judgments of Routines
by Kindergarten Children (fun predictor deleted)

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
Time	0.290	0.290	0.084	40.011**	1.466
Last R	0.220	0.365	0.133	35.113**	1.218
Difficulty	-0.185	0.393	0.154	11.594**	0.392
Trial	-0.035	0.408	0.166	6.762**	0.226

**p < .01

-8% of the variance in children's responding, Last R 5%, Difficulty 2%, and Trial 1%. The F at the last step was significant at the .01 level for all four variables.

Fun was not a significant predictor of the children's duration estimates. In fact, close examination of the group regression analysis indicated that it shared a good deal of variance with Time ($r = -.33$) and consequently reduced the F value and usefulness value for Time when entered into the regression equation. The Fun variable not only failed to add to the predictive power of the equation but in fact minimized its power of prediction by taking away from the full significance of Time as a predictor. Thus, a second table has been provided (see Table 16) terminating the analysis at the fourth step before Fun was added into the equation. The usefulness values in Table 15 indicated that Last R was a more potent predictor of the children's responding than the duration of the activity being estimated; however, when Fun was omitted from the equation such was not the case. Relative to the other variables, Time remained the single most important predictor of the children's duration estimates.

The best fitting model for duration estimates of routines made by kindergarteners is provided in Table 17. There were three significant predictors in addition to Time. As shown in Table 15, the correlation coefficient for Last R ($r = .22$) demonstrated that the child's tape setting on the previous trial was predictive of his subsequent response. The positive

TABLE 17

Best Fitting Model Derived from Group Regression Analyses for Duration
Judgments of Routines by Kindergarten and Grade 1 Children

Age Group	Time (b_1) ^a	REGRESSION COEFFICIENT					Constant (b)	Multiple R	Se	F^b
		(b_2)	(b_3)	(b_4)	(b_5)					
Kindergarten	0.197±.059	0.141 (Last R)	0.208 (Diffi- culty)	-0.017 (Trial)	-	3.148	0.408	0.645	23.658**	
Grade 1	0.311±.059	0.164 (Last R)	0.118 (Diffi- culty)	-0.185 (Fun)	-0.016 (Trial)	2.687	0.534	0.610	40.354**	

^aThe quantity following the (+) or (-) is the 95% confidence limit.

^bCumulative F for best fitting model.

**p < .01

correlation coefficient between difficulty and duration estimate ($r = .19$) indicated that when the activity was judged to be "hard" as opposed to "easy", the children tended to make their estimates longer. The correlation coefficient between Trial and duration estimate is a negative one ($r = -.04$) demonstrating that as the children proceeded through the task their estimates of the activities became significantly shorter. However, the R^2 values and usefulness values for these latter two variables were low. Thus, trial and difficulty were of very secondary importance in predicting duration judgments of kindergarteners.

A group slope and standard error was derived from the regression analysis and both are indicated in Table 17. The standard error of .65, which reflects the consistency with which the children were able to estimate the duration of the routines, was high. The mean slope of .20 is very far from the reference slope of 1.0 and suggests that the children had considerable difficulty in making their judgments proportional.

A three-way analysis of variance (block x duration category x activity type) with two levels of activity type nested in each of the four duration categories, was applied to the log-transformed tape setting responses made by the kindergarten children. The results of this analysis are given in Table 18.

Using conservative degrees of freedom, there was a

TABLE 18

Three-Way Analysis of Variance of the Effects of Block,
Duration Category and Activity Type on Duration
Judgments by Kindergarten Children

Source	SS	MS	df ^a	F
B (Block)	0.103	0.103	1	0.247
BS	12.113	0.418	29	
L (Duration)	22.482	7.494	3(1)	17.008**
LS	38.334	0.441	87(29)	
LB	0.346	0.115	3(1)	0.739
LBS	13.568	0.156	87(29)	
A (L) (Activity)	17.732	4.433	4(1)	11.056**
S A(L)	46.510	0.401	116(29)	
B A(L)	0.054	0.013	4(1)	0.100
SBA (L)	15.515	0.134	116(29)	

**p < .01

^aNote that conservative degrees of freedom were used in testing.

significant main effect due to duration category, $F(1,29) = 17.01$, $p < .01$, and a significant main effect for activity type nested in duration category, $F(1,29) = 11.06$, $p < .01$. This finding indicated that other qualities of the activities in addition to their duration significantly influenced the children's judgments in at least one duration category. There were no significant differences between estimates given in the first block of trials as opposed to the second block, confirming the negligible importance of the effect of Trial in the group regression analysis.

To examine how well the kindergarten children were able to discriminate the routines on the basis of duration, mean judgments for the four duration categories were compared using a Newman-Keuls multiple comparison test. As shown in Table 19 not all duration categories were significantly discriminated from one another. The children significantly differentiated the short activities from the medium, $Q = 5.16$, $k = 2$, $p < .05$, long, $Q = 7.39$, $k = 3$, $p < .01$, and extra-long activities $Q = 9.64$, $k = 4$, $p < .01$. Medium length activities were also judged to be significantly shorter than the extra-long activities, $Q = 4.48$, $k = 3$, $p < .01$. The children did not, however, significantly distinguish activities that were in the medium duration category from those in the long category, or those of long duration from those of extra-long duration.

Histograms have been drawn in order to illustrate the results of the Newman-Keuls analyses. Figure 5 shows the

TABLE 19

Newman-Keuls Tests Comparing Duration Judgments
of Routines According to Duration Category
for Kindergarten Children

- I - Activities of 1 min Duration
- II - Activities of 5 min Duration
- III - Activities of 15 min Duration
- IV - Activities of 30 min Duration

	II	III	IV
I	5.158*	7.389**	9.635**
II		2.231 ^{n.s.}	4.477**
III			2.246 ^{n.s.}

*p < .05

**p < .01

df error = 29

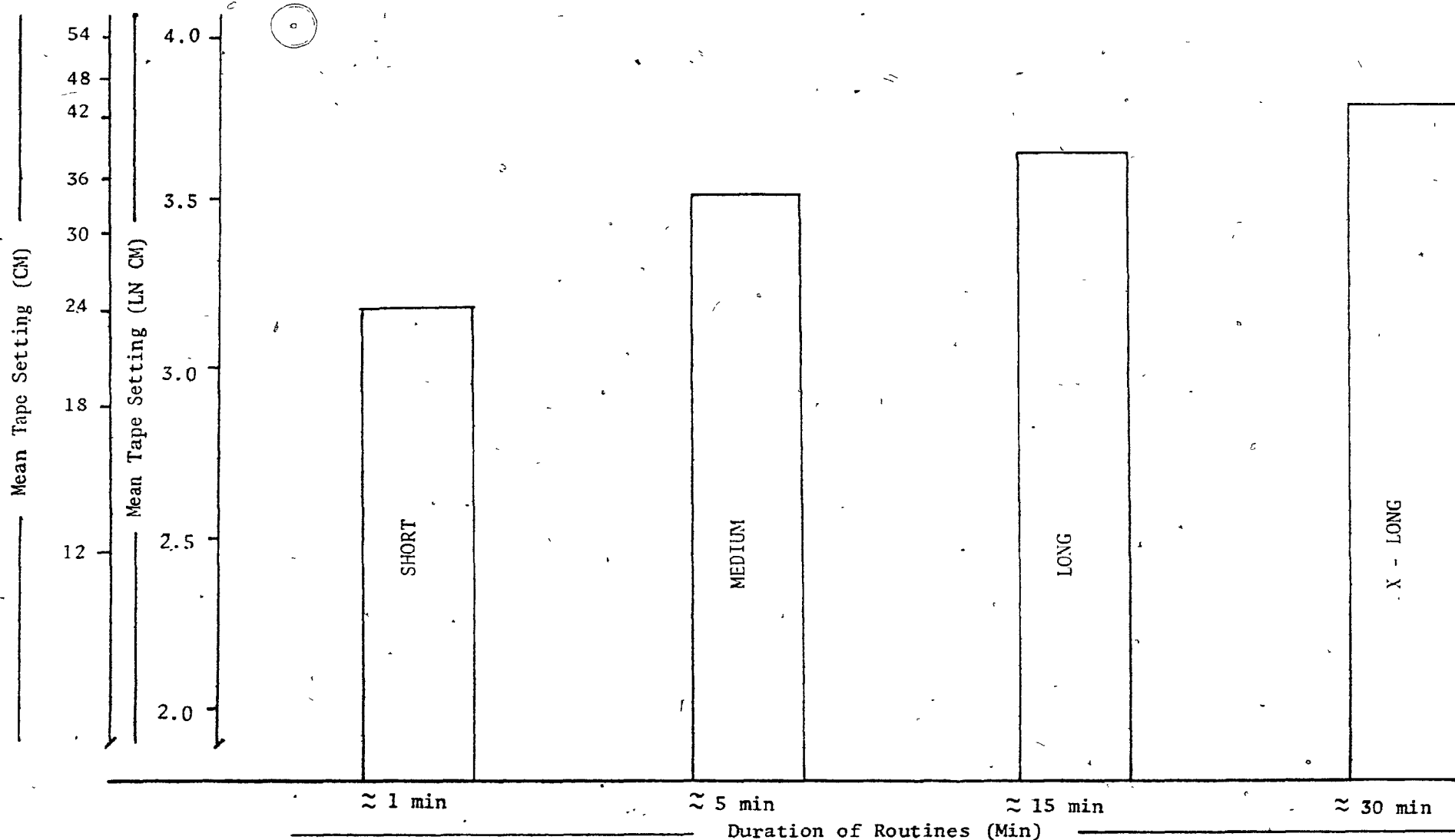


FIGURE 5. Mean judgments of duration of routines collapsed over activity type for kindergarten children.

mean log-centimeter tape setting responses given by kindergarteners for the four duration categories. In Figure 6, the histogram is further broken down to indicate the children's mean duration judgments for each separate activity. This latter histogram illustrates the significant main-effect for activity type nested in duration from the three-way analysis of variance. Although it is impossible to specify what qualities of the activities influenced the children's temporal judgments when the duration of the two activities were the same, of note is the fact that within the "short" and "medium" duration categories, relatively passive activities were judged to be longer than activities wherein the child was active.

Thus results of the group analyses for kindergarten children indicated that the actual duration of the routines was the most important predictor of their temporal estimates. Nevertheless, Time was not a powerful predictor and regression analyses showed that the children tended to rely on their previous response in making their judgments. The children were quite variable in their responding and had difficulty making their time judgments proportional. Longer activities were more difficult to discriminate from one another than shorter ones.

Group Analysis: Grade 1

The results from the grade 1 group regression analysis are shown in Tables 20 and 21. All 5 independent measures

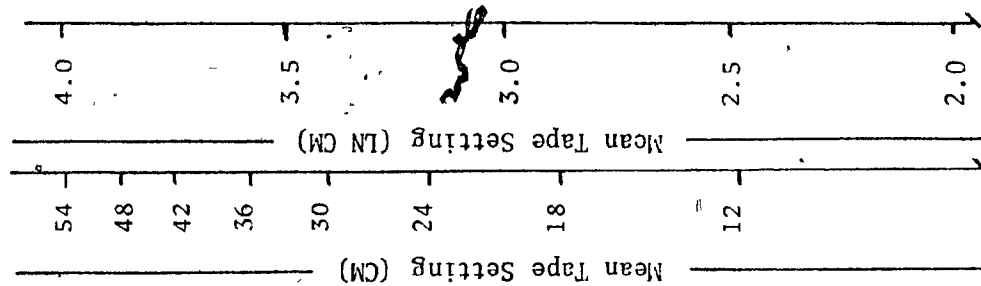


FIGURE 6. Mean judgments of duration of individual activities for kindergarten children.

TABLE 20

Group Regression Analysis for Duration Judgments of Routines
by Grade 1 Children (all predictors included)

N=32

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
Time	0.420	0.420	0.177	72.865**	2.310
Last R	0.227	0.487	0.238	45.181**	1.324
Difficulty	0.205	0.511	0.262	30.610**	0.869
Fun	-0.112	0.524	0.275	9.401**	0.262
Trial	0.032	0.534	0.285	7.143**	0.196

TABLE 21

Group Regression Analysis for Duration Judgments of Routines
by Grade 1 Children (fun predictor deleted)

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
Time	0.411	0.411	0.169	122.397***	3.794
Last R	0.215	0.475	0.225	43.098**	1.237
Trial	-0.026	0.486	0.237	7.321**	0.207
Difficulty	0.087	0.495	0.245	5.456**	0.153

***p < .001

**p < .01

were significantly predictive of the first graders' duration estimates of routines ($p < .01$). The F and usefulness values indicated that Time was the most important of the predictors, accounting for 18% of the variance in the children's responding. Thus the percentage of variance accounted for by duration alone was twice as great for the grade 1 children compared to the kindergarteners. Yet the relative importance of the other variables was very much the same for the two age groups. The percentage of variance accounted for by Last R, Difficulty, Fun and Trial for the grade 1 children were 4%, 2%, 2% and 1% respectively.

As with the kindergarten group, Difficulty, Fun and Trial were far less important than Time and Last R as predictors. Once again, close scrutiny of the group regression analysis demonstrated that Fun, which correlated $-.34$ with Time, served to weaken the predictive power of the equation. Table 21 provides a summary of the results of the group regression analysis when Fun was removed from the equation. With the Fun variable deleted, the F and usefulness values for Time both increased considerably.

Table 17 summarizes the best fitting model for the grade 1 regression analysis. Last R, Trial and Difficulty influenced the children's duration judgments of routines in the same way as for the kindergarten sample. Fun correlated negatively with the dependent measure ($r = -.11$) indicating that children in the first grade estimated "fun" routines to be

longer than "no fun" routines.

Table 17 also presents the slope and standard error for the grade 1 group. The standard error of .61 was rather large suggesting that first graders, like the kindergarten group, did not consistently estimate durations of routines. The slope of .31 indicated that these children were able to be more proportional in their judgments than kindergarten children but the slope still compared poorly with the reference of 1.0.

A three-way analysis of variance (block x classroom group x activity type) was applied to the log transformed estimates given by the grade 1 children. Duration category could not be included as a factor because no available computer program could handle the unequal number of activities in each duration category as well as the unequal sample sizes.

The results of the three-way analysis of variance are shown in Table 22. Using conservative degrees of freedom, there was a significant main effect for activity type, $F(1,30) = 40.78$, $p < .01$, indicating that aspects of the activity (which here might include duration as well as other qualities) significantly influenced the children's duration judgments. Block was not a significant factor, confirming the relative unimportance of the Trial variable in the group regression analysis.

The major variable of interest was duration. However, duration category could not be included in the analysis of

TABLE 22

Three-Way Analysis of Variance of the Effects of Block,
Classroom Group and Activity Type on Duration
Judgments by Grade 1 Children

Source	SS	MS	df ^a	F
G (Classroom Group)	5.814	5.814	1	1.558
S (G)	111.964	3.732	30	
R (Block)	0.207	0.207	1	1.493
RG	0.437	0.437	1	3.147
R S (G)	4.167	0.139	30	
A (Activity)	84.455	12.065	7(1)	40.784**
AG	4.440	0.634	7(1)	2.144
A S (G)	62.123	0.296	210(30)	
RA	0.312	0.045	7(1)	0.519
RAG	0.453	0.065	7(1)	0.753
RA S (G)	18.046	0.086	210(30)	

**p < .01

^aNote that conservative degrees of freedom were used in testing.

variance. Therefore, the more conservative Scheffé test of multiple comparisons was used in order to determine how well the grade 1 children discriminated activities of different duration.

Comparisons were performed on the mean log-transformed tape setting responses made by children in both classroom groups for activities in each duration category. The summary of the results of this analysis are given in Table 23. As was the case with the kindergarten group, first graders could not always discriminate between the routine activities on the basis of duration. Short activities were judged to be significantly shorter than medium length, $F(3,28) = 10.49$, $p < .05$, long, $F(3,28) = 15.09$, $p < .01$, and extra-long, $F(3,28) = 8.93$, $p < .05$, activities. However, medium length activities were not estimated to be significantly different from long or extra-long activities and the one activity in the extra-long duration category was not judged to be significantly different from activities in the long duration category. This last instance of failure to discriminate on the basis of duration seems to have been due to the fact that the children misconceptualized the extra-long activity. Rather than judging the duration of the lunchtime period (i.e. from class dismissal to return to school), many of the children later reported that they had given an estimate of how long it took them to eat lunch.

Figure 7 provides a histogram which illustrates the results of the above analysis. When mean duration estimates

TABLE 23

Scheffé Tests Comparing Duration Judgments
of Routines According to Duration Category
for Grade 1 Children

- I - Activities of 2 min Duration
- II - Activities of 10 min Duration
- III - Activities of 20 min Duration
- IV - Activity of 60 min Duration

COMPARISON

F

I, II	10.492*
I, III	15.085**
I, IV	8.929*
II, III	3.635
II, IV	1.060
III, IV	1.667

*p < .05

**p < .01

d.f. error = 28

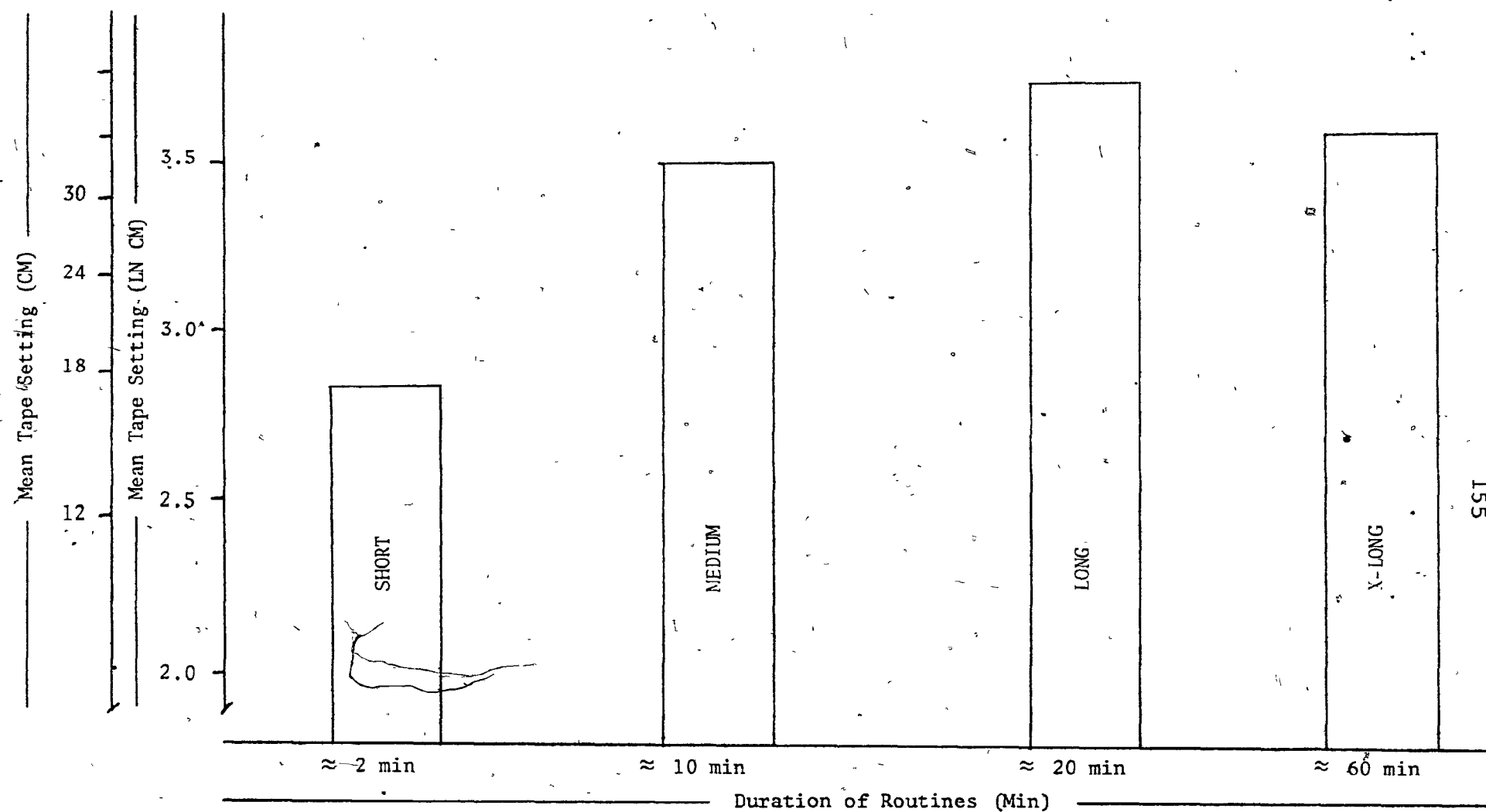


FIGURE 7. Mean judgments of duration of routines collapsed over activity type for grade 1 children.

were examined for the individual activities as shown in Figure 8, there was a good deal of overlap between activities of different duration categories. Of note was the fact that for first graders, as was the case with kindergarteners, the waiting interval (in the short duration category) was judged to be longer than an active interval of the same duration.

To summarize, the group analyses demonstrated that first graders were better able to take into account the duration of school routines than kindergarten children. Actual duration was a much more potent predictor of their time judgments. Nevertheless, these children also had difficulty being consistent and making their judgments proportional and as a result they tended to base their estimates on their previous response. When estimates for activities of different duration categories were compared, again the longer activities were more difficult to discriminate.

Inter-Group Comparison of Individual Results

Individual regression analyses, identical in format to the group analyses, were performed on the 16 duration estimates of 8 routines given by each of the 62 children. Appendix J provides a summary of the best fitting regression model for each subject. In order to determine whether or not an additional variable other than Time was significantly predictive, a conservative cut-off of $p \leq .01$ was once again employed. Among the kindergarten children, there were three

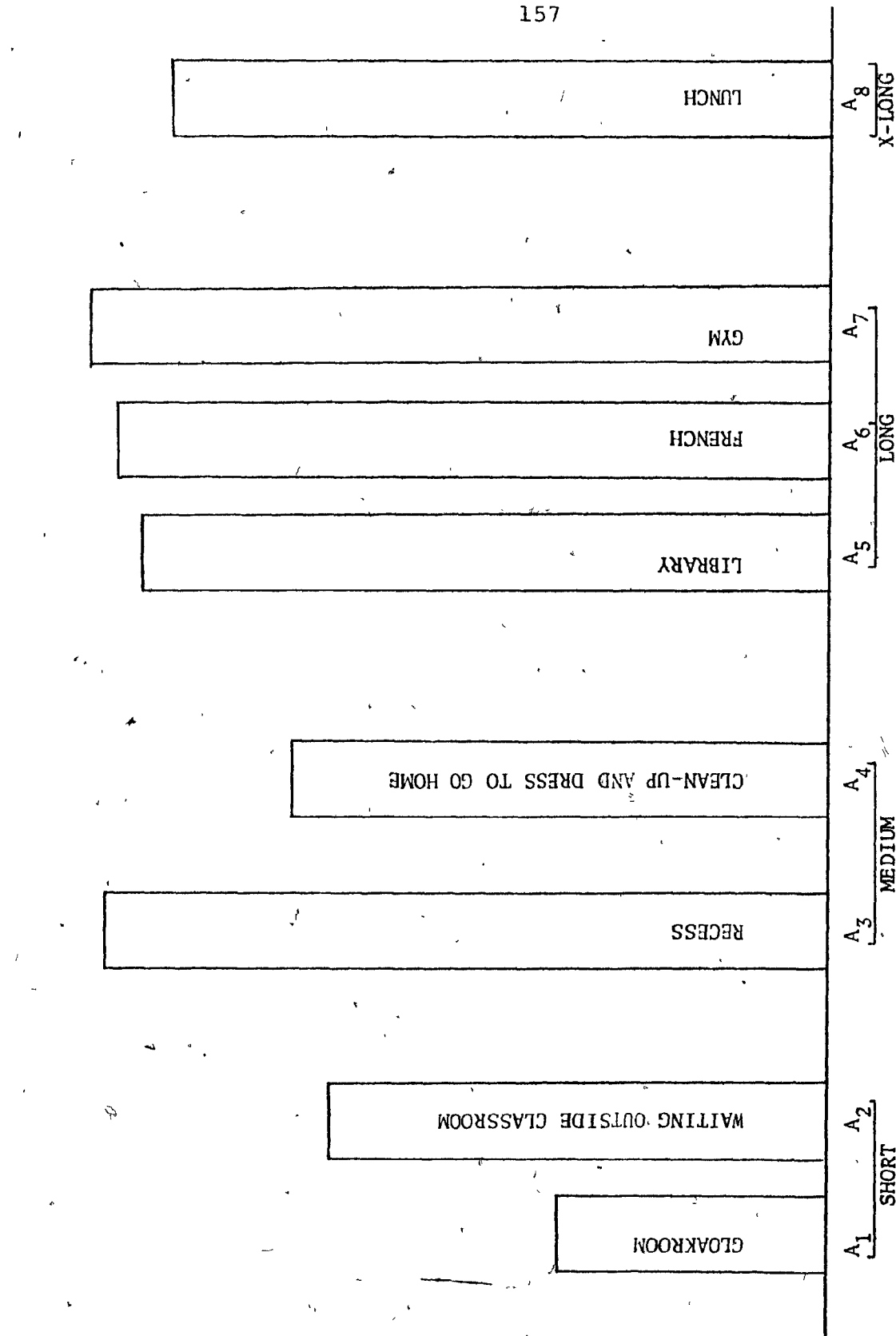
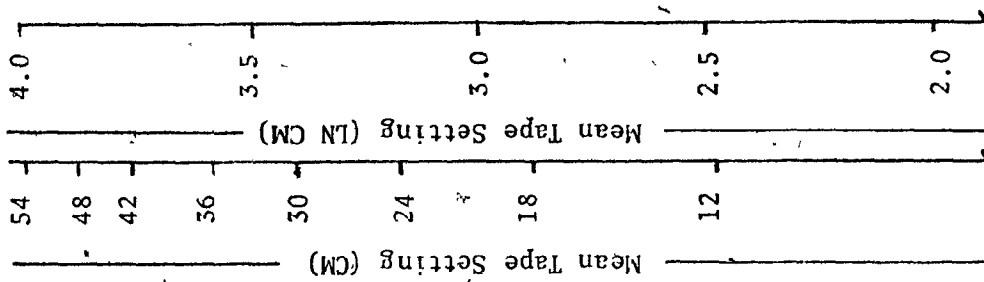


FIGURE 8. Mean judgments of duration of individual activities for grade 1 children.

subjects (subjects 2, 22 and 23) for whom Trial was an additional predictor, and, within the grade 1 sample, Trial and Last R were significant additional predictors for one subject (subject 2). In addition, there were a number of subjects for whom the cumulative F at the first step (i.e. for Time) was not significant (criterion: $F(1,14) = 4.60, p = .05$). Twelve kindergarten children (subjects 5, 7, 9, 10, 11, 12, 13, 15, 16, 20, 27, 28) and eight grade 1 children (class 1: subjects 3, 8, 9, 13, 14, 15; class 2: subject 24) were apparently unable to take into account the duration dimension when estimating the routines. There was a larger proportion of children in the kindergarten group than in the grade 1 sample who had this difficulty; as well, there were more children in class 1 (defined by the school as the less intelligent class) than class 2 for whom Time was not a significant predictor variable.

The mean standard errors for kindergarten and first graders were .45 and .44 respectively. Both values were considerably lower than the group regression standard error estimates. Table 24 summarizes the results of the one-way analysis of variance which confirmed the lack of significant age group differences. The kindergarten children showed greater individual differences in consistency than the grade 1 children as indicated by the standard deviations of their scores (kindergarten SD = .23, grade one SD = .11).

A one-way analysis of variance was also performed on the

TABLE 24

One-Way Analysis of Variance of the Effect of Age Group on Standard
Error Scores of Duration Judgments of Routines

Source	SS	MS	df	F
G (Age Group)	0.000	0.000	1	0.013
S(G)	1.932	0.032	60	

TABLE 25

One-Way Analysis of Variance of the Effects of Age Group on Slopes
of Duration Judgments of Routines

Source	SS	MS	df	F
G (Age Group)	0.274	0.274	1	5.091*
S(G)	3.229	0.054	60	

*p < .05

individual slopes in order to examine possible age group differences. The summary of this analysis is given in Table 25. The mean slope for the kindergarten group was .17 and .30 for first graders. The analysis indicated significant age group differences, $F(1,60) = 5.09$, $p < .05$ in slope scores and once again the standard deviations demonstrated larger individual differences for kindergarten children (kindergarten, $SD = .28$; grade 1, $SD = .17$).

Comparison of Duration Estimates of Tones
with Duration Estimates of Routines

The group regression analyses for the routines were re-run excluding Fun and Difficulty variables so that they might be more easily compared with the results obtained for the two age groups on the tone judgments. The summary of these results are given in Table 26.

Comparison of Table 26 with Table 9 illustrates that both kindergarten and grade 1 children were able to take into account duration when judging tones and routines. However, time was a much more potent predictor of their tone estimates than of their routine estimates. In addition, when the children had difficulty taking into account the duration of routines, Last R took on greater relative importance as a predictor variable for both age groups. In fact for the kindergarten children, Last R was almost as important as Time in predicting duration estimates of school routines when only three

TABLE 26

Group Regression Analysis for Duration Judgments of Routines by
Kindergarten and Grade 1 Children (Forced Order Entry for
Time, Last R and Trial Only)

Age Group	Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
Kindergarten	Time	0.290	0.290	0.084	47.371**	1.669
	Last R	0.220	0.365	0.133	33.754**	1.126
	Trial	-0.037	0.382	0.146	7.204**	0.237
Grade 1	Time	0.411	0.411	0.169	119.315***	3.541
	Last R	0.215	0.475	0.225	44.952**	1.244
	Trial	-0.026	0.486	0.237	7.466**	0.203

***p < .001

**p < .01

predictors were included in the regression equation. Trial assumed relative unimportance as a predictor of the children's estimates of both tones and routines.

The individual regression analyses also attest to greater difficulty in judging duration of routines than tones. Only three children from the two age groups were unable to take into account duration of tones, whereas twenty of the 62 children were unable to do so when estimating the duration of routines.

Of further interest were the differences in slope and standard error scores for the two duration tasks. Group multiple regression analyses indicated that the children were a good deal more consistent and more proportional in their judgments when estimating tones (kindergarten, $Se = .57$; grade 1, $Se = .46$; kindergarten, $b = .79$; grade 1, $b = .74$) than when estimating routines (kindergarten, $Se = .65$; grade 1, $Se = .61$; kindergarten, $b = .20$; grade 1, $b = .31$).

The Newman-Keuls and Scheffé tests offered further support for the fact that kindergarten and grade 1 children found it more difficult to take into account duration category when estimating routines. Both age groups were able to discriminate all five tone lengths from one another, however, kindergarten children and first graders had difficulty comparing durations of routines.

EXPERIMENT 2C: Cognitive and Behavioral Measures as
Predictors of Children's "Precision" on Duration
Tasks

Method

Major Considerations in Choosing Materials for Assessment of
Cognitive and Behavioral Skills

Tests and rating scales were used to assess each child on a variety of cognitive and behavioral skills. The indices used were chosen primarily on the basis of current theoretical speculation regarding the processes underlying perception of duration. However, in addition, two other factors determined the choice of these particular measures: information obtained through a questionnaire and discussions with elementary school teachers; and considerations regarding using a lower socioeconomic sample.

Pilot questionnaire. Due to the paucity of research concerning the relationship between temporal skills in children and other areas of cognitive and behavioral functioning, the present investigator, as part of a pilot exploratory project, designed and circulated a "time" questionnaire among a dozen school teachers (kindergarten to grade 3). A sample of this questionnaire can be found in Appendix K. The questionnaire was used to obtain information on what teachers teach their pupils about time (both formally and informally). Teachers were also requested to describe any children in their class who seemed to have difficulty understanding time and to

indicate whether or not the child presented any other academic or behavioral difficulties. Lastly, teachers were asked to speculate about possible causes of temporal problems.

The teachers in this small sample claimed that as many as 20% of their students seemed to have difficulties either performing temporal skills or understanding temporal concepts.

A number of target problems were pinpointed, the most frequent of which included: distractability, lack of organization (e.g. "He always has trouble completing his work and cleaning up on time"), forgetting routines (e.g. "Constantly asks what's happening next"), failure to be punctual (e.g. "He plays on the way to school and forgets to come"), poor language (e.g. "Doesn't know the days of the week or the months of the year), poor attention span, trouble learning clocktime (e.g. "Doesn't know when he gets up, when he goes to bed, whether it's A.M. or P.M.") and difficulty sequencing. A range of accompanying problems and possible attributions were also noted: poor memory, poor arithmetic and spatial ability, immature language, and poor fine and gross motor skills. Interestingly, the attributes most commonly cited by teachers in this lower class school was lack of organized routine at home.

Although responses were many and varied, the experimenter found the teacher's observations helpful in constructing a rating scale concerning "the child's temporal behavior in the classroom" and was able to test whether or not some of the above target behaviors were predictive of ability to judge

duration on the experimental tasks.

Considerations regarding using a lower socioeconomic sample. Due to the fact that the children in the present study came from a lower socioeconomic community, several precautions were taken in choosing test battery materials.

Though by no means definitive, there is a body of evidence suggesting that language measures are particularly responsive to the effects of social disadvantage. Perhaps the most rigorous and therefore best known research that deals with this subject has been carried out by Deutsch and his colleagues at the Institute of Developmental Studies (Deutsch, 1965, 1973). One of the major findings from their famous 4-year "Verbal Survey" was that lower class status is associated with poorer language functioning as measured by a variety of standardized tests (e.g. Lorge-Thorndike, Weschler Intelligence Scale for Children, Verbal Fluency and Concept Sorting Test, Cloze Test, Peabody Picture Vocabulary Test, Wepman Test of Auditory Discrimination). Their results were obtained using children as young as 5 years and they claimed that the association was even stronger for fifth graders than first graders. Decline in IQ and some verbal scores confirmed by longitudinal data have led these researchers to postulate the notion of "cumulative deficit".

Other authors have also noted differences in language and cognitive style as a function of socioeconomic status (e.g. Hess, Shipman, Brophy and Bear, 1968; Loban, 1963).

The research in this area, however, has lacked consistency and methodological differences have made it difficult to generalize across studies (Hess, 1970). Nevertheless, there is one consistent finding which to date remains unrefuted: Subjects of lower socioeconomic status obtain lower IQ scores on standardized tests than their middle class peers (Deutsch, 1973).

This finding has led researchers and clinicians to be aware of factors which might hinder the lower-class child in the testing situation (e.g. anxiety, decreased motivation, complex instructions).

In the present study, only standardized tests which have been found to be reasonably "culture-fair" were used. In addition, raw scores were the measures of interest as opposed to standard scores or percentile ratings; the purpose being to examine within-sample variability rather than comparing the sample with some normative population. Tests were chosen which would put as few demands on the child's expressive language abilities as possible and every effort was made to make the testing situation a relaxed one. In addition, wherever possible the experimenter chose test items that would be familiar to the children. On several accounts, this meant that the experimenter designed tasks rather than using standardized tests which would have been readily available.

Materials and Procedure for Assessment
of Cognitive and Behavioral Skills

In administering the test battery, the following procedure was used. Every effort was made to see the child in the morning to increase the probability that he would be awake and alert. Initially, time was spent getting acquainted with each child and helping him to feel at ease in the testing situation. Throughout testing, care was taken to ensure that instructions were simple and direct and that they had been adequately understood. The full battery of tests took on the average 25 min; however, this varied considerably as most of the tests were untimed and breaks were given whenever the child seemed overly anxious or fatigued.

Knowledge of clocktime. This task was designed in order to assess each child's knowledge of clocktime (CLOCK). A cardboard toy clock with movable hands was used. The experimenter first presented the child with hourly clock settings, then half-hour, then quarter hour and finally minutes. Two trials were given for each category of setting and if there was any hesitancy on the child's part, additional trials were given. On the basis of the child's responses, he was assigned to one of five possible categories: (a) child has no knowledge of clocktime at all, (b) child knows hours, (c) child knows half-hours, (d) child knows quarter-hours, and (e) child knows minutes. Testing terminated following two consecutive failures on a single clock setting.

Measure of non-verbal ability. The raw score from The Coloured Progressive Matrices (Raven, 1974) was used as an index of non-verbal ability (NV). This untimed, standardized test was especially designed for use with young children and old people and can be described as "a test of observation and clear thinking." The three sets of matrices used (A, A_B, B) have been designed to cover all the perceptual reasoning processes of which children under 12 years are usually capable. When used in conjunction with a vocabulary test, it offers a measure of "general intelligence."

The children completed all three sets of the test comprising a total of 36 problems. The book form of the test was used. Each problem in the Matrices consists of a brightly-coloured incomplete picture of series of pictures depicted at the top of the page and six small drawings at the bottom, only one of which is the correct missing piece of the puzzle.

A standard administrative procedure was followed. The experimenter opened the book to the first illustration and said:

Look at this (pointing to the upper figure). You see, it is a pattern with a piece cut out of it. Each of these pieces (experimenter points to each in turn) is the right shape to fit the space, but only one of them is the right pattern. Only one is right. Point to the piece which is quite right.

Sets A_B and B contain a series of pictures with a segment left out rather than one single picture. The instructions

were as follows:

You see how it goes, that, that-that, what will this one be? Point to the right one to go here. Be careful. Look at each in turn: only one is quite right. Which one is it?

Each child progressed through all problems at his own rate and a raw score of number of correct responses was calculated.

Measure of verbal ability. The raw score from the Peabody Picture Vocabulary Test (PPVT) - Form A was used as an index of verbal ability (V). The PPVT is a standardized test involving receptive language and is typically used to assess verbal IQ. The test is short (10-15 min), untimed and no oral response is required. It is of high interest value for young children and particularly appropriate for the withdrawn child who lacks confidence as every child must have a series of successes before attacking difficult items.

In this test, the examiner says a word and the child then indicates by pointing, which one of four pictures corresponds to that spoken word. The standard procedure of administration was followed. The experimenter placed the book of test pictures in front of the child and introduced the test by saying:

I want to play a picture game with you. See all the pictures on this page. I will say a word, then I want you to put your finger on the picture of the word I have said. Let's try one. . . . Now I am going to show you some other pictures. Each time I say a word, you find the picture of it.

Testing proceeded and continued until the child made six errors

in eight consecutive presentations. The raw score was used as an index of each child's performance.

Numerical Memory Subtest: McCarthy Scales of Children's Abilities. The forward series from the Numerical Memory Subtest (DS) of the McCarthy Scales of Children's Abilities (McCarthy, 1970) yielded a measure of memory capacity uncontaminated by verbal ability. This task is similar to other digit span subtests (e.g. Digit Span Subtest of Weschler Intelligence Scale for Children) wherein the child is asked to recall a series of digits, each series increasing in length by one item.

Standard instructions were used: "Now let's see how well you can say numbers. I'm going to say two, and you repeat exactly what I say. . . ." For each series there were two possible trials. Success on trial 1 was awarded two points whereas failure on trial 1 but success on trial 2 was awarded one point. A possible 10 points could be earned and the task was terminated following failure on both trials of a single series. The subtest itself is given in Appendix L.

Memory span for unrelated words. A second memory task consisting of unrelated words (UW) was designed by the present experimenter. The test itself can be seen in Appendix M. While standardized memory tasks similar to this are available (e.g. Auditory Attention Span for Unrelated Words Subtest of The Detroit Tests of Learning Aptitude), the writer wanted to ensure that all words appearing in the lists were familiar to

the children so that failure to recall could not be attributed to problems in comprehension. One syllable words of equal frequency of occurrence were chosen from those English words which occur most frequently (100 or over per million) as documented by The Teacher's Word Book of 30,000 Words (Thorndike and Lorge, 1931). Children were asked to recall lists of words varying in length from 2 to 8 items, each list containing one more unrelated word than the list prior. If the child failed to recall a list correctly and in the correct order, an alternative list with the same number but different words was presented.

The examiner gave the following set of instructions:

I am going to say some words to you. Listen carefully and when I get all through I want you to say just what I said. Tell the words in the same order if you can. Do you understand? Now listen carefully--say 'hat . . . bank.'

The words were presented at the rate of one word per second. If the child started recall before the complete series had been given or if the child became noticeably distracted, the examiner stopped and presented the subject with an alternate trial. Success on trial 1 received a score of two while success on trial 2 earned the child one point. The task was terminated following failure on both trials of a series. A total of 14 points could be gained.

Oral Commissions Subtest: The Detroit Tests of Learning Aptitude. The Oral Commissions Subtest (OC) from The Detroit

Tests of Learning Aptitude, (Baker and Leland, 1967) was used as a third measure of memory capacity. This memory task encompasses a number of features in addition to simple recall as it requires that the child comprehend instructions and retain information while at the same time carrying out tasks. The child must listen to the instructions in full before carrying out the tasks and the series become more difficult in that the number of tasks to be performed increases by one each time. A fifth series consisting of 5 tasks was added to the test in order to make it more difficult and thus add greater range to the scores. Test items are given in Appendix N.

The experimenter gave the following instructions:

I am going to tell you some things to do. You listen and do just what I tell you to do after I get all through. Try to do the things in the same order as I say them. Remember now, listen first to, all I have to say before you start doing.

The commissions were given slowly allowing from 10 to 15 sec for the pupil to do what was requested of him in the test. The experimenter remained absolutely still and avoided making any gestures or glances that might serve as cues for the child.

For each series, there were two possible trials in case of failure on the first attempt. Scoring proceeded as follows. On trial 1, one point was given for each task successfully carried out in proper sequence. If the child had any difficulty on trial 1 (i.e. forgetting a commission, improper sequence, failure to follow instructions as given), he was given trial

2 and .5 points were awarded for each successful task carried out over and above the number successfully completed on trial 1. There was a total of 15 possible points.

Total memory score. The latter three tests were used to assess memory capacity. Each yielded a raw score. Not knowing a priori how highly correlated the results of these tests would be, the three scores were also combined to yield a sum out of 39 reflecting "general memory capacity" (TOT).

Teacher's academic rating. For their own purposes, each teacher had assessed and rated their students as to "general academic standing" prior to the study. The teachers had tested each child individually on a variety of readiness skills and assigned them to categories. The teacher's academic rating of the child (TAR) was used as a general index of academic performance and ranged from 1 to 4 for the kindergarten children and 1 to 3 for the grade 1 students.

The kindergarten teacher described her evaluation as being based on the child's performance on a number of readiness skills including knowledge of numbers, shapes, colours, letter recognition, letter sounds, sequencing ability, fine motor coordination. The grade 1 teachers used such criteria as reading skills (which included word recognition, letter sounds, spelling) oral and written expression, and arithmetic ability. The grade 1 children were grouped according to their relative standing in the class. The criteria used by the two grade 1 teachers differed somewhat as the two classes had been

selectively streamed at the outset of the school year.

Child's temporal behavior in the classroom. To assess the child's temporal behavior in the classroom, the present investigator designed a five-point rating scale consisting of six items which teachers filled out for each child individually. The items were as follows:

- (t₁) Arrives on time for school
- (t₂) Ready to leave when teacher dismisses class
- (t₃) Aware of school routines (e.g. knows when it is time for recess, gym, snack, storytime, lunch-time, etc.)
- (t₄) Can estimate how long it will take to do routine activities
- (t₅) Starts and completes work on time
- (t₆) Organizes or plans work well

The teacher rated the child on a scale from one (labelled "always") to five (labelled "never") for each of the above items. Prior to teachers filling out the scales, the purpose of the task was explained and the meanings of items clarified. Once the forms were completed, the experimenter reviewed each child's rating scale with the teacher to ensure that she had responded to the specific behavior in question and to guard against possible "halo" effects.

Temporal sequencing ability. Ability to sequence events in time (SEQ) was assessed using several series of 9x7 cm picture cards which represented activities that all the children

would be familiar with (e.g. taking a bath, making a sandwich, shopping for groceries, building a snowman). Sample items are shown in Appendix O.

The task was designed by the present experimenter because standardized tests of sequencing ability (e.g. Picture Arrangement of Weschler Intelligence Scale for Children) use activities that lower-class children may not be familiar with. Pre-testing was carried out with a separate sample of children of similar age and social class to ensure that as the number of cards in the sequence increased, the difficulty of sequencing cards in their correct order also increased. A Guttman procedure was used to determine this.

The test series ranged from sequencing activities arranged on only three cards up to activities portrayed on six cards. There were two possible trials for each number series. Successful sequencing on trial A yielded one, two, three or four points according to order of difficulty. If the child failed to sequence group A correctly, no points were awarded and correct sequencing of group B earned him .5 points less than could be received for group A. A possible 10 points could be gained and testing was terminated when a child failed to sequence correctly on both trials of a single series. Number of seconds taken to complete a sequence correctly was also monitored. This measure taken from the first successful series was used in combination with the raw score (formula: $\text{raw score} \div \text{number of sec taken to respond}$) to yield a final score

reflecting temporal sequencing ability.

The instructions used for this task were as follows. The experimenter placed the picture cards in front of the subject and said:

Here are some pictures. Look at them carefully. They tell a story. But the way I have put them on the desk (experimenter motions with hand from left to right) is wrong. They are in the wrong order. Can you put them the way they are supposed to go? Go ahead and do it as fast as you can.

For each series, the child was given the following prompt:

"Let's look at another one. How should they go? Put them in the right order for me so they tell a story."

Results

Three types of analyses were used to determine which cognitive and behavioral measures might predict children's "precision" in judging the duration of tones and familiar school routines.

First, a Pearson product-moment correlation was performed on the measures derived from the test battery. Separate analyses were carried out for the two age groups. In both cases there were a total of 20 variables. The teacher's rating for each item of the scale concerning the child's temporal behavior in the classroom was included as a separate measure. In addition, two scores reflecting each child's "precision" in making duration judgments were taken from the individual regression analyses on both the tones data and on the routines data. The first score was the standard error estimate taken from the first step of the individual regression analysis. This measure reflected "precision" in the sense that it indicated how consistent the child had been in making his duration judgments. The second score was obtained by calculating how deviant each child's slope was from a reference line of 1.0 using the formula $b - 1 - SE(b)$. This measure of "precision" indicated how proportional the child had been in making his duration judgments (i.e. his ability to reproduce clocktime intervals). Thus the 20 variables included in the Pearson analysis were: consistency measure

for tones (SEE), accuracy measure for tones (ACC), consistency measure for routines (RSEE), accuracy measure for routines (RACC), chronological age (CA), non-verbal score (NV), verbal score (V), teacher's academic rating (TAR), digit span score (DS), unrelated words score (UW), oral commissions score (OC), total memory score (TOT), knowledge of clocktime rating (CLOCK), temporal sequencing score (SEQ) and the teacher's rating of the child's temporal behavior in the classroom items 1, 2, 3, 4, 5, 6 ($t_1, t_2, t_3, t_4, t_5, t_6$).

Second, all variables with the exception of ACC, SEE, RACC, RSEE and TOT (The Pearson analysis indicated that this score did not add any significant additional information over and above that provided by the indices of memory independently), were included in a principle factor analysis (SPSS package) calculated separately for the two age groups. Thus there were 15 independent measures in all. Four factors emerged for the kindergarten children accounting for 73.9% of the total variance and five factors accounting for 71.7% of the variance were delineated for the grade-1 children. A varimax procedure was used to rotate all factors and factor scores were derived for the variables.

Lastly, two sets of regression analyses were carried out for each age group: one set concerning the results from the tone judgments and the other based on the results obtained from duration judgments of routines. Factor scores for each factor identified served as predictor variables and the two

scores reflecting the child's "precision" in making duration judgments of tones (ACC and SEE) and routines (RACC and RSEE) were used as criterion measures. Thus, four multiple regression analyses were run for each age group. The first two were used to determine which factors significantly predicted the children's consistency and accuracy in making duration judgments of tones; the second two analyses examined the predictive power of these factors in determining consistency and accuracy in estimating duration of routines.

Pearson Product-Moment Correlation Analysis

The correlation matrix for the kindergarten and grade 1 samples are displayed in Tables 27 and 28 respectively. Due to the large number of correlations performed and the small sample sizes, caution should be used in interpreting the results.

Age group differences. Of particular note, were the number of significant correlations for the kindergarten group as opposed to first graders. While many of the cognitive and behavioral measures taken from the kindergarten sample were highly correlated, such was not the case for the older children. Thus it would seem that the grade 1 children were considerably more differentiated in their academic and behavioral skills than the younger sample.

Precision on duration judgments of tones vs. Routines. A second interesting feature of the Pearson analysis was the

TABLE 27

Correlation Matrix of Test Battery Measures and Measures of
Precision for Kindergarten Children

	RACC	SEE	ACC	AGE	NV	V	TAR	DS	UN	OC	TOT	t ₁	t ₂	t ₃	t ₄	t ₅	t ₆	CLOCK	SEQ
Consistency on Routings (RSEE)	-.59***	.29	-.28	-.09	-.18	-.11	-.07	.08	-.01	.13	.10	.07	-.19	-.28	-.26	-.08	-.24	-.12	-.12
Accuracy on Rotuines (RACC)		.03	.08	-.11	.03	-.17	-.16	-.32	-.47**	-.14	-.33	.02	-.28	-.19	-.18	-.34	-.13	-.10	-.22
Consistency on Tones (SEE)			-.67***	-.55**	-.52**	-.48**	-.58***	-.30	-.28	-.36*	-.41*	.23	-.40*	-.48**	-.52**	-.36*	-.43*	-.36*	-.16
Accuracy on Tones (ACC)				.59***	.33	.29	.33	.09	.22	.17	.20	.06	.38*	.20	.37*	.24	.34	.23	-.17
Chronological Age (CA)					.24	.52**	.56***	.33	.51**	.41*	.51**	-.08	.51**	.59***	.58***	.47**	.53**	.36*	.17
Non-Verbal Score (NV)						.26	.55**	.25	.06	.29	.28	.03	.18	.40*	.42*	.30	.35	.53**	.35
Verbal Score (V)							.61***	.41*	.52**	.56***	.64***	-.02	.45*	.61***	.55**	.37*	.49**	.10	-.07
Teacher's Academic Rating (TAR)								.42*	.44*	.60***	.64***	.06	.30	.77***	.80***	.67***	.68***	.28*	.40
Digit Span Memory Score (DS)									.69***	.39*	.80***	.00	.37*	.29	.40*	.47**	.46**	.43*	.53*
Unrelated Words Score (UN)										.31	.72***	-.08	.50*	.44*	.52**	.53**	.45*	.44*	.53*
Oral Commissions Score (OC)											.84***	-.12	.17	.38*	.46**	.45*	.36*	.19	.03
Total Memory Score (TOT)												-.09	.38*	.45*	.57***	.60***	.51**	.39*	.42
Arrives on Time for School (t ₁)													-.11	-.13	-.17	-.20	-.15	.09	.04
Ready to Leave when Teacher Dismisses Class (t ₂)														.47**	.56***	.53**	.67***	.16	.02
Aware of School Routines (t ₃)															.83***	.63***	.73***	.20	.31
Can Estimate How Long It will Take To Do Routine Activities (t ₄)																.82***	.84***	.21	.28
Starts and Completes Work on Time (t ₅)																	.81***	.20	.38
Organizes or Plans Work Well (t ₆)																		.21	.31
Knowledge of Clocktime (CLOCK)																			.56**
Temporal Sequencing Score (SEQ)																			

***p < .001; **p < .01; *p < .05

TABLE 28

Correlation Matrix of Test Battery Measures and Measures of Precision for Grade 1 Children

	RACC	SEE	ACC	AGE	NV	V	TAR	DS	UW	DC	TOT	t ₁	t ₂	t ₃	t ₄	t ₅	t ₆	CLOCK	SEQ
Consistent on Routines (RSEE)	-.78**	-.03	-.21	-.26	-.05	-.38*	-.37*	-.26	-.39*	-.01	-.24	-.40*	-.61**	-.46**	-.55**	-.55**	-.49**	-.24	-.23
Accuracy on Routines (RACC)		.14	.12	.21	-.13	.12	.09	-.00	.15	-.32	-.14	.25	.47**	.30	.13	.48**	.27	-.06	.06
Consistency on Tones (SEE)			-.52**	.24	-.02	.05	.09	-.28	-.13	-.24	-.31	.00	-.01	-.27	-.19	.10	-.15	-.23	-.35*
Accuracy on Tones (ACC)				-.19	-.21	-.04	.01	.29	.08	.14	.24	.13	.11	.27	.29	.09	.07	.11	.13
Chronological Age (CA)					.15	.39*	.00	.07	.26	-.06	.07	.30	.14	.09	.25	-.01	.13	.39*	-.03
Non-Verbal Score (NV)						.33	.22	.14	.04	.09	.13	-.01	.04	-.01	.34	.18	.35*	.05	.41*
Verbal Score (V)							.26	.15	.40*	.08	.23	.17	.06	.45**	.61**	-.14	.18*	.30	.29
Teacher's Academic Rating (TAR)								.35*	.21	.16	.31	-.04	.24	.30	.41*	.34	.28	.35*	.39*
Digit Span Memory Score (DS)									.57***	.21	.75***	.01	.09	.20	.30	-.01	.38*	.16	.42*
Unrelated Words Score (UW)										.28	.72***	.20	.06	.33	.37*	.01	.22	.37*	.24
Oral Commissions Score (OC)											.76***	-.24	-.32	.10	.37*	-.17	-.07	.35*	.14
Total Memory Score (TOT)												-.08	-.13	.25	.46**	-.10	.20	.38*	.34*
Arrives on Time for School (t ₁)													.48**	.45**	.38*	.42*	.48**	.07	-.17
Ready to Leave when Teacher Dismisses Class (t ₂)														.33	.30	.68***	.53**	.13	-.05
Aware of School Routines (t ₃)															.70***	.29	.13	.21	.30
Can Estimate How Long it Will Take to do Routine Activities (t ₄)																.30	.32	.39*	.40*
Starts and Completes Work on Time (t ₅)																	.45**	-.03	-.03
Organizes or Plans Work Well (t ₆)																		.05	.16
Knowledge of Clocktime (CLOCK)																			.28
Temporal Sequencing Score (SEQ)																			

***p < .001; **p < .01; *p < .05

interrelationships among the accuracy and consistency scores for the two types of duration tasks. Accuracy and consistency measures were highly correlated within each type of duration estimation task for both kindergarten children (tones: $r = -.67$, $p < .001$; routines: $r = -.59$, $p < .001$) and first graders (tones: $r = -.52$, $p < .01$; routines: $r = -.78$, $p < .001$). The correlations were negative because a high SEE (RSEE) score was reflective of poor consistency whereas a high ACC (RACC) score indicated good ability to be accurate. Thus children who were accurate in judging duration of tones were also consistent in their estimates of this stimulus material. Similarly, children who could estimate the duration of routines accurately also tended to be consistent in their responding on this task. However, correlations between accuracy measures for the two types of duration tasks and between the two consistency measures were not significant. Children of both age groups who were accurate in giving estimates of tones were not predictably accurate in their duration judgments of routines and consistency on one kind of task did not correlate significantly with consistency on the other.

Interrelationships among scores of memory capacity. Scores on the Digit Span memory subtest of the McCarthy Scales of Children's Abilities (DS) and performance on the Unrelated Words memory task (UW) were significantly correlated for both kindergarten children ($r = .69$, $p < .001$) and first graders ($r = .57$, $p < .001$). For kindergarteners, performance on the

Oral Commissions subtest of The Detroit Tests of Learning Aptitude (OC) was significantly correlated with performance on DS ($r = .39, p < .05$); in contrast, this correlation was not significant for the grade 1 sample. Performance on UW was unrelated to performance on OC for both age groups. Thus it would seem that the Oral Commissions subtest, which demands recall of verbal material but in addition requires the child to comprehend instructions and retain this information while carrying out tasks, measured abilities unrelated to simple recall of verbal and non-verbal material.

Interrelationships among the items on the teacher's rating scale of the child's temporal behavior in the classroom.

The items on the rating scale concerning the child's temporal behavior in the classroom were filled out by the classroom teacher. Thus there was no way of objectively determining the reliability of these ratings. In reviewing each child's rating scale with the kindergarten teacher, the experimenter found that she had some difficulty responding selectively to the items and tended to give a child either high or low ratings regardless of the content of the item. Though the teacher was given assistance in responding to the specific behaviors under inquiry, "halo" effects may have occurred. With the exception of t_1 (Arrives on time for school), all of the items in the scale were significantly correlated with one another for the kindergarten children. This may have been partially due to the teacher's tendency to respond globally to

the questionnaire. However, given the large number of significant correlations among other measures as well, it may have indicated that children at this developmental stage are not yet differentiated in their cognitive and behavioral skills. The fact that t_1 did not correlate significantly with any other items was not surprising in that the teacher reported that many of the children were dependent upon parents, siblings or friends to take them to school and therefore had little control themselves as to whether or not they were punctual.

There were far fewer significant correlations among the items on the rating scale for the grade 1 children. The two teachers seemed to have less difficulty comprehending the task and responding selectively. As shown in Table 28, t_1 was significantly correlated with all other items. In addition, items concerning punctuality and organization (t_1 , t_5 : starts and completes work on time; t_6 : Organizes or plans work well) were significantly correlated with one another and the child who was rated as being aware of when in the day specific routines took place (t_3) was also rated as being adept in estimating the duration of these routines (t_4).

Factor Analysis

Kindergarten sample. Four factors emerged from the factor analysis performed on the measures obtained from the kindergarten children (see Table 29). Before varimax rotation,

TABLE 29

Loadings on Four Varimax Factors for Fifteen Variables

Taken from Kindergarten Test Battery

VARIABLES	FACTORS			
	I	II	III	IV
1. Chronological Age (AGE)	.31	.34	.58*	.09
2. Non-Verbal Score (NV)	.09	.01	.25	.83*
3. Verbal Score (V)	.14	.18	.89*	-.04
4. Teacher's Academic Rating (TAR)	.42*	.15	.61*	.54*
5. Digit Span Score (DS)	.10	.79*	.28	.14
6. Unrelated Words Score (UW)	.25	.84*	.32	-.05
7. Oral Commissions Score (OC)	.06	.08	.74*	.20
8. Knowledge of Clocktime (CLOCK)	-.13	.59*	.05	.59*
9. Temporal Sequencing Score (SEQ)	.16	.66*	-.24	.58*
Teachers Rating Scale				
10. Arrives on time (t_1)	-.58*	.10	.15	.14
11. Ready to leave (t_2)	.54*	.38	.37	-.20
12. Awareness when routines (t_3)	.60*	.12	.53*	.34
13. Can estimate duration routines (t_4)	.71*	.19	.51*	.31
14. Starts/completes work on time (t_5)	.72*	.32	.32	.23
15. Organizes/plans work well (t_6)	.74*	.27	.39	.22
Sum of Squared Loadings	2.98	2.67	3.31	2.11
% Total Variation	45.7%	12.2%	8.4%	7.5%

**|loadings| > .40

Factor I accounted for 45.7% of the variance, Factor II for 12.2%, Factor III for 8.4% and Factor IV for 7.5%. Prior to discussion of these factors it should be mentioned that variables referred to here as loading "high" on a factor are those that yielded an absolute factor loading $\geq .40$.

Variables with high positive loadings on Factor I included the teacher's academic rating (TAR), t_2 , t_3 , t_4 , t_5 and t_6 . One measure, t_1 loaded highly but negatively perhaps acting as a suppressor variable. Difficulties with this item of the rating scale in the case of the kindergarten sample have already been discussed. Since all the above measures were subjective ratings made by the teacher, Factor I, for purposes of easier identification was labelled "teacher's perception of the child."

The variables with high loadings on Factor II, UW, DS, SEQ and CLOCK were either measures designed to tap memory capacity directly or skills relying heavily on recall. Thus this clustering of variables was referred to as a "memory" factor.

The verbal score (V), OC, TAR, AGE, t_3 and t_4 loaded heavily on the third factor. These measures reflected the child's general cognitive developmental level and in particular his verbal skills ("cognitive - verbal skills"). In addition, Factor III included the teacher's subjective rating of the child's awareness of when familiar school routines take place and his ability to estimate their duration. These

teacher's ratings may also have been influenced by how verbal the child was in the classroom.

Loading highly on Factor IV were the non-verbal score (NV), CLOCK, SEQ and TAR. These measures again were indicative of the child's general cognitive developmental level but this cluster stressed non-verbal abilities ("cognitive - non-verbal skills").

Grade 1 sample. The factor analysis performed on the test battery measures obtained from the grade 1 children yielded five factors. A summary of the factor loadings for all independent variables are shown in Table 30. Factor I accounted for 28.4% of the variance, Factor II for 16.6%, Factor III for 10.6%, Factor IV for 8.4% and Factor V for 7.7%.

Four items from the teacher's rating of the child's temporal behavior in the classroom loaded heavily on Factor I. These included t_2 , t_5 , t_1 and t_6 . The children's performance on the OC memory task loaded negatively on this factor. The items from the teacher's rating scale all reflected either the child's punctuality or his efficiency in organizing school work. Accordingly, the factor was labelled "teacher's perception of child's punctuality and efficiency in organizing work."

The remaining two items from the teacher's rating scale, t_3 and t_4 , loaded on Factor II along with CLOCK, V and TAR. The rating scale items concerned the teacher's perceptions

TABLE 30

Loadings on Five Varimax Factors for Fifteen Variables

Taken from Grade 1 Test Battery

VARIABLES	FACTORS				
	I	II	III	IV	V
1. Chronological Age (AGE)	.07	.08	.02	.12	.82*
2. Non-Verbal Score (NV)	.08	-.03	.90*	-.02	.15
3. Verbal Score (V)	-.05	.49*	.39	.04	.59*
4. Teacher's Academic Rating (TAR)	.22	.47*	.37	.30	-.30
5. Digit Span Score (DS)	.07	.07	.21	.87*	-.05
6. Unrelated Words Score (UW)	.01	.32	-.05	.74*	.30
7. Oral Commissions Score (OC)	-.44*	.47*	.03	.31	-.16
8. Knowledge of Clocktime (SEQ)	-.11	.56*	-.09	.34	.24
9. Temporal Sequencing Score (SEQ)	-.13	.35	.64*	.29	-.13
Teachers Rating Scale					
10. Arrives on time (t_1)	.69*	.18	-.19	-.01	.44*
11. Ready to leave (t_2)	.86*	.13	-.03	.05	.03
12. Awareness when routines (t_3)	.33	.79*	.00	.00	.09
13. Can estimate duration routines (t_4)	.25	.79*	.33	.13	.22
14. Starts/completes work on time (t_5)	.83*	.16	.09	-.06	-.24
15. Organizes/plans work well (t_6)	.67*	-.09	.35	.40	.13
Sum of Squared Loadings	2.82	2.56	1.84	1.89	1.64
% Total Variation	24.4%	16.6%	10.6%	8.4%	7.7%

*|loadings| > .40

of the child's awareness of routines. Thus Factor II was indicative of the child's knowledge of clocktime and routines as well as his verbal cognitive functioning ("cognitive - verbal skills and ability to estimate time").

Factor III was grossly referred to as a "non-verbal" factor. Only two measures yielded factor loadings $> .40$: the non-verbal score (NV) and temporal sequencing score (SEQ).

Factor IV ("memory" factor) was also defined primarily by two variables: DS and UW, both indicative of memory capacity. The teacher's rating of the child's ability to organize his work (t_6) also loaded on this factor but less heavily (.41).

Those variables with high loadings on Factor V included AGE, V and t_1 . Thus this factor was representative of both cognitive verbal skills and the child's punctuality in arriving at school on time.

Multiple Regression Analysis

Factor scores were used to determine which factors predicted the children's consistency and accuracy in judging the duration of tones and routine school activities. The criterion measures used in the regression analyses were SEE, ACC, RSEE and RACC. In the case of the kindergarten group there were four possible predictors; for the first graders, there were five.

Kindergarten sample. When standard error was used as the dependent measure in the regression analysis for the kinder-

garten group (see Table 31), two factors: Factor III ("cognitive - verbal skills") and Factor IV ("cognitive - non-verbal skills") were significant predictors of consistency in judging the duration of tones. Factor III accounted for 23% of the variance and Factor IV, 9%. In both cases the F at the last step was significant at the .05 level.

Table 32 summarizes the results of the group regression analysis performed on the kindergarten data for tones when accuracy was used as the criterion measure. Only one factor was significantly predictive of the children's precision in judging the duration of tones. Factor III ("cognitive - verbal skills") accounted for 16% of the variance, again the F at the last step being significant at the .05 level. This factor was clearly the most important predictor as the total percentage of variance accounted for by all factors combined was a mere 18%.

Summaries of the group regression analyses which examine the predictive power of factors in determining the kindergarten children's precision in judging the duration of routines are given in Tables 33 and 34. Results indicated that none of the factors was significantly predictive of consistency in estimating routines. In fact, all four factors combined only accounted for 9% of the variance. However, Factor II ("memory") did predict the accuracy with which kindergarten children judged duration of routines ($p < .05$). This factor accounted for 17% of the variance in children's responses.

TABLE 31

Group Regression Analysis for Kindergarten Children: Factors as
Predictors of SEE of Tone Duration Judgments

N=30

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
FACTOR III	-0.475	0.475	0.226	7.453*	0.231
FACTOR IV	-0.334	0.561	0.315	4.500*	0.123
FACTOR I	-0.284	0.624	0.390	3.268	0.080
FACTOR II	-0.116	0.638	0.407	0.746	0.018

TABLE 32

Group Regression Analysis for Kindergarten Children: Factors as
Predictors of ACC of Tone Duration Judgments

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
FACTOR III	0.396	0.396	0.157	4.260*	0.144
FACTOR I	0.140	0.413	0.171	0.479	0.016
FACTOR IV	0.103	0.421	0.177	0.237	0.008
FACTOR II	0.087	0.427	0.182	0.160	0.005

*p < .05

TABLE 33

Group Regression Analysis for Kindergarten Children: Factors as
Predictors of RSEE for Duration Judgments of Routines

N=30

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
FACTOR I	-0.263	0.263	0.069	1.944	0.072
FACTOR IV	-0.132	0.300	0.090	0.547	0.020
FACTOR III	0.036	0.306	0.094	0.095	0.003
FACTOR II	0.056	0.307	0.094	0.017	0.001

TABLE 34

Group Regression Analysis for Kindergarten Children: Factors as
Predictors of RACC for Duration Judgments of Routines

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
FACTOR II	-0.406	0.406	0.165	4.413*	0.147
FACTOR III	-0.239	0.457	0.209	1.354	0.043
FACTOR I	-0.119	0.471	0.222	0.391	0.012
FACTOR IV	0.125	0.479	0.229	0.220	0.007

*p < .05

Grade 1 sample. Tables 35 and 36 summarize the results of the multiple regression analyses for first graders when precision on tone duration judgments was examined. None of the five factors was predictive of either consistency or accuracy. In fact, the total percentage of variance accounted for by all factors combined was small both when the criterion measure was consistency (17%) and accuracy (14%).

In contrast to the tones analyses, several factors predicted the precision with which grade 1 children estimated routines (see Tables 37 and 38). Factor I ("teacher's perception of child's punctuality and efficiency in organizing work") significantly predicted the accuracy of their estimates ($p < .01$), accounting for 24% of the total variance. When consistency was used as the dependent measure, two factors were predictive. Again Factor I was a powerful predictor accounting for 31% of the variance and Factor II, ("cognitive - verbal skills and ability to estimate time") accounted for 16%. The F's at the last step were significant at the .01 level for both these factors.

TABLE 35

Group Regression Analysis for Grade 1 Children: Factors as
Predictors of SEE of Tone Duration Judgments

N=32

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
FACTOR IV	-0.248	0.248	0.061	1.844	0.067
FACTOR II	-0.205	0.322	0.103	1.268	0.044
FACTOR V	+0.167	0.362	0.131	0.834	0.028
FACTOR I	+0.051	0.366	0.134	0.077	0.003
FACTOR III	-0.043	0.368	0.136	0.056	0.002

TABLE 36

Group Regression Analysis for Grade 1 Children: Factors as
Predictors of ACC of Tone Duration Judgments

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
FACTOR II	0.261	0.261	0.068	2.137	0.077
FACTOR V	-0.184	0.320	0.102	1.058	0.037
FACTOR IV	0.180	0.367	0.134	1.008	0.034
FACTOR III	-0.151	0.396	0.157	0.710	0.023
FACTOR I	0.108	0.411	0.169	0.365	0.012

TABLE 37

Group Regression Analysis for Grade 1 Children: Factors as
Predictors of RSEE for Duration Judgments of Routines

N=32

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
FACTOR I	-0.560	0.560	0.314	18.871**	0.491
FACTOR II	-0.404	0.690	0.477	9.814**	0.197
FACTOR IV	-0.250	0.734	0.539	3.757	0.067
FACTOR V	-0.143	0.748	0.560	1.226	0.021
FACTOR III	-0.092	0.754	0.568	0.505	0.008

TABLE 38

Group Regression Analysis for Grade 1 Children: Factors as
Predictors of RACC for Duration Judgments of Routines

Variable	Simple r	Multiple R	R Square	F to Enter	Usefulness
FACTOR I	0.490	0.490	0.241	8.806**	0.257
FACTOR V	0.098	0.500	0.250	0.350	0.010
FACTOR II	0.091	0.508	0.258	0.302	0.009
FACTOR III	-0.063	0.512	0.262	0.146	0.004

**p < .01

GENERAL DISCUSSION

Discussion of the results concerning the present series of investigations will proceed in the following manner.

First, major findings concerning the young child's ability to estimate duration of tones will be reviewed. Extraneous factors which influenced children's time judgments of these more simple stimuli will be examined. Second, comparisons will be made between the children's performance in estimating familiar routines as opposed to tones. The way in which temporal estimates of routines were affected by methodological and motivational variables will be discussed. Lastly, cognitive and behavioral skills which best predicted the children's precision on both estimation tasks will be examined.

Estimation of Tone Durations

The results from both studies combined, support the contention that children between the ages of 5 and 10 years are able to estimate duration. When pure tones were used and a simplified response measure employed, first graders, fourth graders and kindergarteners alike demonstrated that they were able to take into account duration without explicit feedback. These group results were further enhanced by individual analyses which showed that of the 115 children who participated in the studies, there were only 3 (two kindergarteners, one

first grader) who failed to use actual duration in making their temporal judgments.

Comparisons between estimates given by 6 and 7-year-old children and young adults demonstrated that children were less able to profit from information provided by the standard and had some difficulty discriminating variable tones of longer duration. When intervals less than 12 seconds were used, the children consistently overestimated variable tones relative to the standard. Nevertheless, the duration of the tones significantly predicted estimates given by all children and they performed at a level comparable to older subjects.

Kindergarten children also had no difficulty discriminating tones ranging from 2 to 25 seconds. They did not differ from first graders either in their ability to be consistent or in their ability to make their time judgments proportional to the tone lengths presented. Variability in responding was considerable but the children demonstrated excellent proportionality in their estimates. Slope scores obtained for kindergarteners (.79) and grade 1 children (.74) were very close to the ideal value of 1.0. In addition, individual analyses revealed that none of the subjects relied more heavily on the extraneous variables of trial or last response in making their judgments. Sex was also not a significant factor influencing children's estimates.

Thus, contrary to the findings obtained by previous investigators (e.g. Crowder and Hohle, 1970; Goldstone, Boardman

and Lhamon, 1958; Goldstone and Goldfarb, 1966; Smythe and Goldstone, 1957), these results demonstrated that children younger than 8 years are able to judge duration of arbitrary stimuli without the assistance of kinaesthetic cues or explicit feedback. Crowder and Hohle (1970) suggested that young children can be trained to improve the accuracy of their estimates. The need for such training, however, may be more a function of the method used than of the child's capabilities in estimating duration. The present findings support the hypothesis that children perceive duration quite accurately before they have acquired adult-like temporal concepts and conventional time units. It would seem that psychophysical studies so far have been unable to demonstrate this because the conceptual response measures used to have been too sophisticated to reflect the young child's perceptual abilities. Using cross-modality matching, the children who participated in these experiments had no difficulty making the connection between duration and line length. Thus, by giving children a response measure which took advantage of their more highly developed spatial abilities (Piaget, 1969), they were better able to communicate their understanding of duration.

Studies regarding the perception of the concept of one second (Goldstone, Boardman and Lhamon, 1958; Goldstone and Goldfarb, 1966; Smythe and Goldstone, 1957), have already demonstrated that different time estimation methods yield significant differences in failure rates, consistency and

accuracy of estimates made by 6 and 7-year-olds. Those methods which children found easiest to use were production accompanied by kinaesthetic cues (Goldstone, Boardman and Lhamon, 1958) and the method of constant stimuli using two-category responses (Goldstone and Goldfarb, 1966). The method of reproduction has also been a preferred method for use with young children (e.g. Crowder and Hohle, 1970; Fraisse and Orsini, 1958). The degree and kind of verbal mediation involved in using these response measures is still unknown (Clausen, 1950). If the young child's perception of time is to be better understood, then future investigators need be concerned with examining the processes that are involved in making time judgments using these different methods.

One means of exploring those extraneous factors which influence children's time judgments is to alter various aspects of the methodology employed. Another, is to manipulate various stimulus contextual properties and examine their effects on duration experience. Both were used in this investigation of the young child's ability to estimate tones.

It is not possible to directly compare the results obtained using cross-modality matching with and without a standard because different samples of grade 1 children were used and the length of variable intervals was also changed. Nevertheless some conclusions can be drawn about the effects of the spacing of intervals and the type of standard given. Based on the findings of previous investigators (e.g. Gregg,

1951; Ross and Katchmer, 1951; Stevens and Gallanter, 1957), it is likely that first graders were more proportional in their time judgments and better able to distinguish between intervals of variable length as a consequence of logarithmically spacing the duration of tones. As these authors would have predicted, with unequal spacing, the slope was steeper at the lower end and flatter over the upper part of the range.

Presenting a range initially as opposed to giving a standard at the outset of each trial may also have assisted first graders in being more discriminant in their time estimates. The anchor tones may have reduced the "central tendency effect" caused by the standard (Stevens and Gallanter, 1957). However, a dramatic increase in both group standard error and intra-subject variability also accompanied use of a range. This would imply that young children do make use of information provided by a standard in order to be more consistent in their judgments. Yet, one important question that has not yet been addressed is whether or not young children can effectively internalize standards for judging duration of arbitrary stimuli such as tones. The children did not make use of the actual values of the range presented. Estimates given for shorter tone lengths were longer than that which might have been expected had they utilized the anchor tones (i.e., 1 sec equivalent to 3.0 cm; 30 sec equivalent to 96 cm). Yet this may merely reflect the general finding that children overestimate tones of short duration regardless

of method employed (Goldstone and Goldfarb, 1966). First graders remarkably increased the proportionality of their time judgments and this may partially have been because using a range allowed some children greater opportunity to use their own internalized standards in comparing durations. Many, however, used the last response as a standard because it was the most recent standard they had.

Last response and trial were of minimal importance in predicting children's estimates of variable tones. When block effects were examined in the second study, however, both kindergarteners and first graders estimated the second block of tones to be longer than the first. This may have been due to the fact that in the absence of a standard presented at the outset of each trial, the children were more easily distracted and fatigued. This may be a further reason why children were less consistent when a range was employed.

The results obtained in the first study demonstrated that stimulus contextual variables are additional extraneous factors which interfere with children's perception of actual duration. First graders and fourth graders differed from adults in that their time judgments were significantly affected by the speed at which tone sequences were presented. It was suggested that children do not use higher cognitive processes to compensate for the effect of speed on their "feeling" of duration. Despite the fact that a child (notably one in grade 4) may have acquired conservation of speed,

his subjective experience of time may still be affected by stimulus rate. The children's estimates also differed as a consequence of the familiarity and organization of tone sequences. When these more complex stimulus contextual variables were altered, the adults' estimates were influenced in the same manner as the children's. More melodious tone sequences were experienced as shorter than repetitious sequences of pure tones. Possible explanations include factors related to organization, attention and motivation. In summary, although children as young as 5 years of age perform well on a duration estimation task, their judgments (and often the judgments of adults as well) are influenced by cognitive variables such as those proposed by Ornstein (1969) and by methodological and motivational factors.

Estimation of Routine Durations

By examining the young child's ability to estimate familiar school routines and comparing their performance on this task with estimations made of tones, the importance of various cognitive skills could be assessed. Although the routine stimuli were more relevant for them, the task relied more heavily on memory and cognitive skills.

The results supported the hypothesis that kindergarten children and first graders would have greater difficulty taking into account the duration of routines than of tones. When routines were estimated, actual duration was still a significant

predictor of their estimates. However, a direct comparative analysis of these results with those obtained using tones showed that the percentage of variance accounted for by Time dropped dramatically for both age groups (i.e. kindergartners: 54% to 8%; first graders: 62% to 17%). But kindergarten children who hardly differed from first graders in their performance on the tones task were even more adversely affected by the switch from tones to routines. The percentage of variance accounted for by Time was half what it was for first graders.

Both age groups discriminated tones of different duration with no difficulty, yet they did have trouble discriminating activities of different duration categories. The longer activities were more difficult to discriminate from one another than the shorter ones. Consistency measures and slope scores also revealed that the routines task was considerably more difficult. The children were more variable in their estimates of routines and the slope scores for the two age groups dropped markedly (kindergarten: tones .79, routines .20; grade 1: tones .74, routines .31). Standard deviation scores for these two measures indicated a high degree of inter-subject variability on both these measures, especially for the younger children. First graders were able to be more proportional in their time estimates of routines whereas there were no significant differences in slope scores when the children estimated tones.

The individual analyses also demonstrated that routines were harder to estimate and that age and academic level were more important determinants of the children's ability to estimate routines than tones. While only three of the 62 children failed to take into account duration of tones, 20 failed in estimating routines. There were more failures in the kindergarten group and in the "less-bright" grade 1 class. Thus while the majority of children did demonstrate the ability to estimate duration of routines, indices of accuracy and consistency revealed that the task was much more difficult for them and resulted in marked differences in performance between the two age groups.

Temporal judgments of stimuli that are familiar and convey a lapse of time are more likely to be affected by the intrusion of nontemporal factors. In this investigation, procedural but not motivational variables interfered with the children's ability to estimate routines.

The children estimated familiar school routines without any feedback provided by a standard. They were told that the longest line represented the entire time they spent at school. This information seems to have been totally ignored by the children as none of them restricted their estimates to the lower end of the scale. What information did they rely on in order to try to make their estimates proportional to the duration categories of activities presented? The results indicated that while last response was not an important

predictor of children's estimates of tones, both age groups relied more heavily on their previous estimate in judging duration of routines. Thus, when children have difficulty "switching in" to the temporal dimension, they will base their estimate on some extraneous variable such as the last response. The kindergarten children seemed to try to compensate more in that last response was a more useful predictor of their estimates. This age difference and the high degree of inter-subject variability in performance already discussed suggests that some children within the age range of 5 to 7 years may have reliable internal standards for estimating familiar activities and others not.

There was a good deal of overlap between estimates given for activities of different duration categories. Any number of variables concerning both the nature of the activities chosen and the children's subjective evaluation of them could have influenced the children's time judgments. Two motivational variables which have been shown to influence subjective estimates given by adults (e.g. Loehlin, 1959) were systematically examined. However task difficulty and task pleasantness were of minimal importance in predicting time estimates given by the children. In addition, even though the kindergarteners had greater difficulty taking into account duration of activities, the relative unimportance of fun and difficulty was the same for the two age groups. Thus, younger children did not compensate by relying on

their affective response to school routines.

Nevertheless, of interest was the direction of effect that these motivational variables had on some children's estimates of routines. The results were consistent with previous findings. As Fraisse (1963) and Doob (1971) would have predicted, when activities were evaluated as being more difficult, children estimated them to be longer. When the children categorized the activity as being "fun" as opposed to "no fun", they also tended to estimate them as longer. In the case of adults, this latter finding has been interpreted within the framework provided by cognitive theorists. When duration estimates are made of more pleasant events in retrospect, more information has been stored and coded and thus the apparent duration lengthens (e.g. Schiff, 1970). However, the children's spontaneous verbal statements during the task indicated that some made the line longer for fun activities because they wanted more of it. There is so little research regarding the influence of motivational factors on time estimates made by young children that at present it is not possible to draw any conclusion regarding the mechanism that may have been involved. A direct motivational influence or motivation as mediated by cognitive variables may have been operating. In the present study, although the active-passive dimension of activities was not systematically examined, children consistently estimated waiting intervals (e.g. waiting outside the classroom for the teacher) to be longer than

intervals filled with activity (e.g. getting dressed and ready to go home).

To summarize, children found it more difficult to estimate routines than tones. In contrast to findings obtained on the tones task, kindergarten children performed even more poorly than first graders and tended to rely more heavily on their previous response in making their time judgments. Motivational factors of fun and difficulty were not influential in determining children's estimates. What factors were responsible then for some children's failure to be accurate and consistent in their estimates? The last group of findings to be discussed were concerned with those cognitive and behavioral skills that differentiated the children in terms of their ability to be precise in estimating both routines and tones.

The Role of Cognitive and Behavioral Skills

Results concerning the interrelationships among the accuracy and consistency scores for the two types of duration tasks suggested that not only were routines more difficult for the children to estimate but that the two tasks involved quite different skills and processes. In the case of both kindergarten children and first graders, precision scores for the two different duration tasks were not significantly correlated with one another. Thus, children who were accurate and consistent in their estimates of tones were not predict-

ably so in their duration estimates of routines. For this reason, findings concerning the relative importance of various cognitive and behavioral skills for a more adult-like perception of time among children will be treated separately for the two types of duration tasks.

A number of cognitive measures predicted the precision with which kindergarten children estimated tones. Factor III, reflecting a cluster of cognitive-verbal skills, was an important predictor of both accuracy and consistency. This may partially have been because children with more highly developed verbal skills were better able to understand instructions and to conceptualize the demands of the task. In addition, it may be that the method used required a good deal of verbal mediation, although some investigators (e.g. Bond and Stevens, 1969; Stevens and Gallanter, 1957) have argued that the cross-modality matching technique is a more direct means of tapping the perceptual process than most other time estimation methods. The fact that chronological age and teacher's academic rating of the child loaded highly on this factor might also indicate that both maturational factors and learning of basic readiness skills are required in order for children to provide accurate and consistent estimates of simple time stimuli. The relative roles of maturation and learning, however, can not be determined from the data obtained. Children's age and general academic performance were highly correlated with one another as were many of

the measures taken for this younger age group:

The children's performance on the oral commissions memory subtest was a further variable that had a high positive loading on Factor III. This index of memory capacity was shown to be quite unique when compared to memory measures involving pure recall in that it tested the child's ability to retain information while carrying out tasks. If there is a distinction between temporal experience and temporal judgment as suggested by some authors (e.g. Mo, 1974), then the ability to estimate time may also involve being able to integrate two separate bits of information which may or may not be complementary.

The kindergarten children's consistency on the tone duration task was also predicted by a cluster of measures reflecting cognitive non-verbal skills (Factor IV). It is more likely then, that the method used, which relied heavily on spatial abilities, was more influential in determining the children's consistency than their accuracy. Children who had a better knowledge of clocktime and who were able to sequence events in time were more consistent in their time judgments. Thus, facility in other areas of temporal functioning may aid children in estimating duration, however, the way in which different temporal skills are related has yet to be determined. The children's knowledge of conventional time units was not predictive of their accuracy in estimating tones.

Thus, though cognitive and behavioral skills of kinder-

garten children are not yet highly differentiated, a number of cognitive skills emphasizing verbal ability were predictive of their precision in estimating tone durations. In striking contrast, none of the factors obtained from first graders performance on various test measures predicted their precision in estimating tones. This could not be attributed to the fact that the measures taken failed to distinguish between the children as most test scores represented quite a range of abilities. Furthermore, these older children were quite highly differentiated in their skills as indicated by few significant correlations between test measures. The fact that no one factor best predicted their precision was not attributable to the possibility that numerous measures equally influenced their precision. The percentage of variance accounted for by all factors combined was minimal.

Three alternative explanations for these findings seem feasible. The first, is that the measures chosen failed to include cognitive and behavioral skills that are important to time estimation ability. However, a wide range of indices was used and predictive power was achieved for the younger children. A second alternative is that older children have mastered the ability to estimate time and that once the young child is proficient in this skill he may use any number of his cognitive assets to aid him in his time judgments. Thus perhaps different children utilize different skills in making their time judgments, each taking advantage of their best

abilities. The difficulty with this interpretation is that first graders were not markedly superior in their performance on the tones task when compared to kindergarten children.

The third and last alternative seems most likely. Only cognitive variables were examined in the present study. It is possible that, beyond the cognitive-verbal skills necessary for conceptualizing the task, the young child's ability to estimate arbitrary time stimuli such as tones is more highly dependent on fundamental perceptual processes than on cognitive variables. The sensory process model which postulates the importance internal timing mechanisms may be more appropriate at this young age level when arbitrary time stimuli are used. Although criticisms of this theoretical model have stemmed from the failure to demonstrate significant correlations between any "internal clock" and estimated duration, many authors (e.g. Bindra, 1976; Doob, 1971; Fraisse, 1971) still believe that sensory processes are involved. If such is the case, then one might speculate that cognitive processes become more dominant as the demands of the estimation task become more complex. This hypothesis was supported by the fact that precision measures on the two duration tasks were not correlated with one another and by results demonstrating that cognitive variables were predictive of the precision with which both kindergarten children and grade 1 children estimated routines.

A cluster of measures designed either to tap memory

capacity directly or skills relying heavily on recall (Factor II) best predicted the kindergarten children's ability to estimate routines. Those children who performed better on both the verbal and non-verbal memory tasks were more accurate in their time judgments. This finding supported Ornstein's (1969) contention that duration in retrospect is dependent upon memory process and that perception of duration is related to the amount of "space" taken to store information. The memory tasks used, however, only examined short-term memory capacity. Further investigations using indices of both short-term and long-term memory might provide information regarding the relative roles of these two processes. Children with better knowledge of clocktime and temporal sequencing were also more accurate in their estimates of routines. These memory and cognitive skills, however, did not effect the children's consistency of performance.

Skills and abilities which best predicted first grader's precision in estimating routines were closely related to the demands of the experimental task. Children perceived by the teacher as being punctual for activities and efficient in organizing their work at school (Factor I) were both more accurate and consistent in their time judgments of routines. Factor II which included a cluster of cognitive-verbal skills and measures reflecting temporal estimation ability also predicted the children's consistency in judging routines. Knowledge of clocktime and the teacher's rating of the child's,

awareness of when school routines took place and his ability to estimate their duration, loaded heavily on this factor. Children with more highly developed verbal skills and children who performed better at school were also shown to be more consistent in their time estimations of routines.

In summary, cognitive and behavioral skills required in order for a young child to be precise in his temporal estimates of tones and routines were found to differ for the two types of duration tasks. This suggested that estimations of tones and routines may involve quite distinct types of temporal processing. The 5 and 6-year-olds needed a certain degree of verbal and non-verbal cognitive facility in order to conceptualize the tones task and in order to be able to use the response measure accurately and consistently. However, perhaps beyond the rudimentary conceptual skills required in order to cope with the demands of the task, precision in estimating simple time stimuli depended upon the efficiency of sensory timing mechanisms.

When kindergarten children were required to estimate routines, memory became a significant factor in determining the precision of their time judgments. For first graders, their ability to perform the more complex task of estimating routines was closely related to the teacher's perception of various temporal behavioral skills manifested in the classroom. Children who were more punctual, more efficient in organizing work and had less difficulty allotting time for

tasks were more accurate and consistent in their estimates of routines within the experimental situation. This direct link between ability to estimate duration and temporal behavioral skills implies that a time estimation apparatus such as the one employed here might be effectively used as a tool for assessing children's temporal abilities as well as a device for training children who have difficulty orienting to classroom routines.

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APPENDIX A

Summary Tables of Newman-Keuls Tests Comparing Duration
Judgments of Variable Tones for Four Age
Groups in Experiment 1A

I - 3 sec tone
II - 6 sec tone
III - 9 sec tone
IV - 12 sec tone
V - 15 sec tone
VI - 18 sec tone
VII - 21 sec tone

Grade 1

	II	III	IV	V	VI	VII
I	12.58	17.65	21.87	22.92	25.78	28.36
II		5.06	9.28	10.34	13.20	15.77
III			4.22	5.28	8.13	10.71
IV				1.06 ^{n.s.}	3.91	6.49
V					2.86	5.43
VI						2.58 ^{n.s.}

Grade 4

	II	III	IV	V	VI	VII
I	12.67	18.87	23.42	25.88	29.12	32.18
II		6.20	10.75	13.21	16.45	19.50
III			4.55	7.01	10.25	13.31
IV				2.46 ^{n.s.}	5.70	6.75
V					3.24	6.29
VI						3.05

$p < .05$ except where indicated
df error = 94

APPENDIX A
(CONTINUED)

I - 3 sec tone
II - 6 sec tone
III - 9 sec tone
IV - 12 sec tone
V - 15 sec tone
VI - 18 sec tone
VII - 21 sec tone

Young Adults

	II	III	IV	V	VI	VII
I	17.38	27.94	32.45	38.50	41.76	44.79
II		10.56	15.06	21.11	24.38	27.41
III			4.50	10.55	13.82	16.85
IV				6.05	9.31	12.35
V					3.26	6.30
VI						3.30

Elderly

	II	III	IV	V	VI	VII
I	8.23	14.12	18.76	21.22	22.15	23.64
II		5.89	10.53	12.99	13.92	15.41
III			4.63	7.10	8.03	9.52
IV				2.46 ^{n.s.}	3.40	4.88
V					0.93 ^{n.s.}	2.42 ^{n.s.}
VI						1.49 ^{n.s.}

$p < .05$ except where indicated
df error = 94

APPENDIX B

Summary Tables of Best Fitting Regression Model for Each
Individual Subject for Duration Judgments
of Tones in Experiment 1A

Grade 1

Subject	b(Time) ^a	Additional ^b Predictor	b ₂ ^c	Se	Multi- ple R	Cumula- ^d tive F
1	.24±.16	Last R	-.11	.09	.91	25.7
2	.24±.05	-	-	.05	.95	112.4
3	.29±.20	-	-	.19	.68	10.3
4	.36±.16	-	-	.15	.81	23.6
5	.37±.30	-	-	.31	.61	7.0
6	.42±.16	-	-	.15	.86	34.0
7	.44±.11	-	-	.11	.93	72.9
8	.49±.10	-	-	.10	.95	113.1
9	.54±.20	-	-	.19	.86	33.5
10	.54±.24	-	-	.23	.82	24.3
11	.54±.20	-	-	.20	.86	34.1
12	.60±.17	-	-	.16	.91	57.6
13	.66±.18	-	-	.17	.92	66.7
14	.66±.24	-	-	.23	.87	36.7
15	.67±.18	-	-	.17	.92	66.8
16	.72±.21	-	-	.20	.91	57.1
17	.74±.23	-	-	.22	.90	49.5
18	.77±.28	-	-	.27	.87	36.2
19	.79±.15	Trial	.01	.10	.98	130.9
20	.82±.18	-	-	.17	.95	101.7
21	.83±.30	-	-	.28	.87	37.1
22	.97±.43	-	-	.41	.82	24.3
23	1.26±.34	-	-	.33	.92	63.1
24	1.42±.23	-	-	.17	.97	174.1
Means	.64±.21			.19	.88	58.0

In this and subsequent tables:

^aThe quantity following the (+) or (-) is the 95% confidence limit.

^bCut-off for significance level of F for additional predictor made conservative ($p \leq .01$).

^cb₂ refers to coefficient of additional predictor.

^dAll cumulative F's are significant at the level $p \leq .05$.

APPENDIX B
(CONTINUED)

Grade 4

Subject	b(Time) ^a	Additional ^b Predictor	b ₂ ^c	Se	Multi- ple R	Cumula- ^d tive F
1	.30±.23	-	-	.22	.63	8.0
2	.39±.09	-	-	.09	.93	82.4
3	.40±.18	-	-	.17	.81	23.0
4	.43±.14	-	-	.13	.89	48.0
5	.45±.17	-	-	.16	.86	34.2
6	.48±.10	-	-	.09	.95	115.3
7	.49±.20	-	-	.19	.85	30.2
8	.52±.18	-	-	.16	.88	40.8
9	.52±.23	-	-	.22	.82	23.8
10	.55±.14	-	-	.13	.93	72.1
11	.56±.17	-	-	.16	.91	54.2
12	.56±.16	-	-	.15	.91	59.2
13	.61±.16	-	-	.16	.92	66.1
14	.61±.16	-	-	.16	.92	66.5
15	.63±.17	-	-	.16	.92	63.6
16	.64±.17	-	-	.16	.92	66.6
17	.65±.12	-	-	.11	.96	154.1
18	.72±.15	-	-	.14	.95	110.2
19	.74±.22	-	-	.21	.90	51.8
20	.74±.15	-	-	.14	.95	114.6
21	.76±.17	-	-	.16	.95	99.7
22	.77±.24	-	-	.23	.90	49.9
23	.77±.19	-	-	.18	.93	78.4
24	.78±.02	-	-	.21	.91	60.6
25	.87±.13	-	-	.13	.97	206.2
26	.99±.21	-	-	.20	.95	104.4
27	1.03±.33	Trial	-.02	.21	.96	57.4
28	1.18±.34	-	-	.33	.91	57.4
29	1.40±.11	-	-	.11	.87	37.5
Means	.67±.17			.17	.90	70.2

APPENDIX B

(CONTINUED)

Young Adult.

Subject	b(Time) ^a	Additional ^b Predictor	b ₂ ^c	Se	Multi- ple R	Cumula- ^d tive F
1	.66±.12	-	-	.12	.96	142.0
2	.67±.10	-	-	.10	.97	203.0
3	.67±.11	-	-	.10	.97	190.5
4	.68±.22	-	-	.21	.89	47.0
5	.69±.15	-	-	.15	.95	100.0
6	.72±.22	-	-	.21	.90	53.1
7	.74±.12	-	-	.12	.97	183.8
8	.75±.52	-	-	.15	.67	9.9
9	.80±.18	-	-	.17	.94	98.0
10	.82±.12	-	-	.12	.97	211.3
11	.83±.12	Last R	-.06	.09	.99	194.1
12	.83±.15	-	-	.15	.96	135.3
13	.83±.22	-	-	.21	.92	67.4
14	.84±.15	-	-	.14	.96	154.2
15	.86±.20	-	-	.19	.94	88.5
16	.88±.16	-	-	.16	.96	135.2
17	.91±.22	-	-	.21	.94	84.8
18	.93±.25	Last R	.15	.17	.97	74.9
19	.93±.19	-	-	.18	.95	111.6
20	.96±.15	Last R	-.08	.11	.99	174.9
21	.97±.15	-	-	.14	.97	205.1
22	.97±.22	-	-	.21	.94	95.1
23	1.01±.15	-	-	.14	.97	219.1
24	1.03±.14	-	-	.14	.98	240.8
25	1.05±.19	-	-	.18	.96	152.7
26	1.08±.15	-	-	.15	.98	232.2
27	1.13±.17	-	-	.16	.97	210.3
28	1.17±.14	-	-	.13	.98	358.3
29	1.18±.15	-	-	.15	.98	273.2
30	1.21±.16	-	-	.15	.98	286.8
Means	.89±.18			.15	.95	157.8

APPENDIX B
(CONTINUED)

Elderly

Subject	b(Time) ^a	Additional ^b Predictor	b ₂ ^c	Se	Multi- ple R	Cumula- ^d tive F
1	.28±.22	-	-	.21	.63	7.9
2	.30±.19	-	-	.18	.71	12.3
3	.34±.22	-	-	.21	.70	11.2
4	.39±.23	-	-	.22	.73	13.9
5	.56±.18	Trial	-.01	.18	.96	70.9
6	.59±.34	Last R	.20	.24	.89	19.8
7	.64±.18	-	-	.17	.92	62.8
8	.65±.23	-	-	.23	.87	36.1
9	.67±.20	-	-	.19	.91	56.5
10	.84±.27	Last R	.17	.18	.95	52.3
11	.86±.23	-	-	.22	.92	67.2
12	.90±.18	-	-	.17	.95	116.3
13	1.04±.08	-	-	.07	.99	875.2
14	1.06±.20	-	-	.20	.96	125.0
15	1.29±.26	-	-	.24	.95	121.1
Means	.69±.21			.19	.87	109.9

APPENDIX C

Summary Table of Newman-Keuls Tests Comparing Standard
Error Scores of Duration Judgments of Tones Across
Four Age Groups in Experiment 1A

I - Grade 1
II - Grade 4
III - Young Adult
IV - Elderly

	II	III	IV
I	2.206	3.472*	0.486
II		1.266	2.692
III			3.958*

*p < .05
df error = 94

APPENDIX D

Summary Table of Newman-Keuls Tests Comparing Slopes of
Duration Judgments of Tones Across Four Age Groups
in Experiment 1A

I - Grade 1
II - Grade 4
III - Young Adult
IV - Elderly

	II	III	IV
I	0.656	5.839**	1.886
II		5.182**	1.230
III			3.953*

**p < .01

*p < .05

df error = 94

APPENDIX E

Follow-Up Questionnaire Given to Adults in Experiment 1.

- (1) How did you find the experiment?
- (2) Did you use any strategies in order to keep track of time?
- (3) What information or cues did you use in order to make your judgments?
- (4) When you were making your judgments, did you respond in terms of how long the duration felt or how long you actually thought it was?
- (5) Were you able to concentrate on the sounds during the task or did your mind wander?
- (6) When the tones were speeded up, did the duration seem longer or shorter?
- (7) When you heard Frère Jacques did the time seem to pass slower or quicker?
- (8) What was your reaction to the other melody?

APPENDIX F

Order of Presentation of Randomized Tones for "Unfamiliar"

Condition in Experiment 1B



APPENDIX G

Summary Tables of Newman-Keuls Tests Comparing Duration
Judgments of Variable Tones for Kindergarten and Grade 1
Children in Experiment 2A

I - 2 sec tone
II - 5 sec tone
III - 11 sec tone
IV - 17 sec tone
V - 25 sec tone

Kindergarten

	II	III	IV	V
I	10.69**	21.47**	24.62**	27.75**
II		10.78**	13.93**	17.06**
III			3.15*	6.28**
IV				3.13*

*p < .05

**p < .01

df error = 29

APPENDIX G

(CONTINUED)

I - 2 sec tone
 II - 5 sec tone
 III - 11 sec tone
 IV - 17 sec tone
 V - 25 sec tone

Grade 1

	II	III	IV	V
I	14.23**	23.09**	28.94**	31.75**
II		8.86**	14.71**	17.52**
III			5.85**	8.66**
IV				2.81*

*This value is marginally significant at the .05 level.

**p < .01

df error = 30

APPENDIX H

Summary Tables of Best Fitting Regression Model for Each
Individual Subject for Duration Judgments
of Tones in Experiment 2A

Kindergarten

Subject	b(Time) ^a	Additional ^b Predictor	b ₂ ^c	Se	Multi- ple R	Cumula- ^d tive F
1	.81±.23	-	-	.24	.95	68.6
2	1.32±.58	-	-	.61	.88	27.8
3	.67±.22	-	-	.24	.93	48.0
4	.75±.13	-	-	.13	.98	185.7
5	.94±.43	-	-	.46	.87	24.8
6	.58±.14	-	-	.14	.96	97.4
7	.70±.22	-	-	.24	.93	52.7
8	.56±.35	-	-	.37	.80	14.0
9	1.17±.45	-	-	.47	.91	36.9
10	.75±.17	-	-	.18	.96	101.7
11	.65±.24	-	-	.25	.91	40.3
12	.59±.18	-	-	.19	.94	60.1
13	.63±.28	-	-	.29	.88	27.2
14	.70±.30	-	-	.31	.89	29.5
15	1.34±.36	-	-	.38	.95	74.8
16	.70±.34	-	-	.36	.86	21.9
17	.56±.37	-	-	.39	.78	12.0
18	.67±.43	-	-	.45	.79	13.1
19	.29±.36	-	-	.39	.54	3.4 n.s.
20	.74±.29	-	-	.31	.90	35.6
21	.70±.34	-	-	.36	.86	22.2
22	1.13±.15	-	-	.16	.99	291.3
23	.48±.56	-	-	.59	.58	4.0 n.s.
24	.82±.32	-	-	.34	.90	34.8
25	.76±.18	-	-	.20	.96	88.7
26	.86±.25	-	-	.27	.94	62.7
27	.80±.40	-	-	.43	.85	21.1
28	.74±.40	-	-	.43	.83	18.0
29	1.26±.71	-	-	.75	.82	17.0
30	1.00±.68	-	-	.72	.77	11.4
Means	.79±.34			.36	.87	51.6

In this and subsequent tables:

^aThe quantity following the (+) or (-) is the 95% confidence limit.

^bCut-off for significance level of F for additional predictor made conservative ($p \leq .01$).

^cb₂ refers to coefficient of additional predictor.

^dAll cumulative F's are significant at the level $p \leq .05$.

APPENDIX H
(CONTINUED)

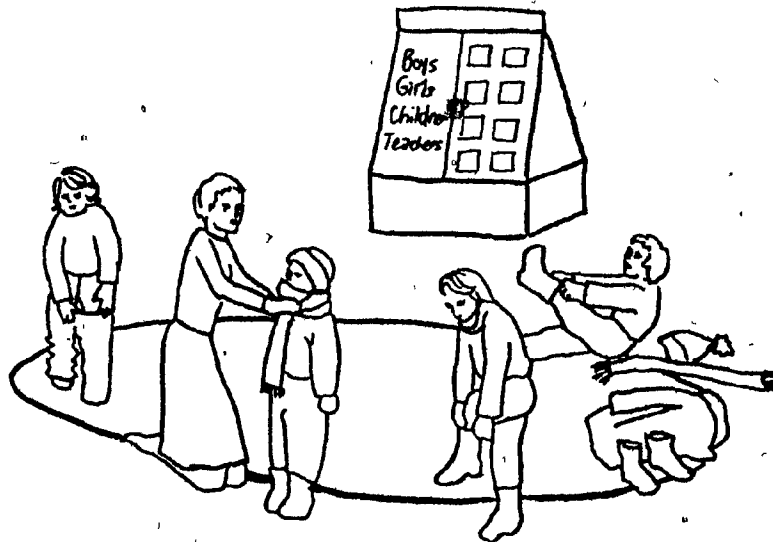
Grade 1

Subject	b(Time) ^a	Additional Predictor ^b	b ₂ ^c	Se	Multi- ple R	Cumula- ^d tive F
Class 1						
1	.76±.32	-	-	.34	.89	30.8
2	.54±.24	-	-	.26	.87	25.8
3	.85±.15	-	-	.16	.98	158.3
4	.68±.53	-	-	.56	.73	8.9
5	.54±.15	-	-	.16	.95	67.9
6	.71±.35	-	-	.37	.86	21.7
7	.67±.27	-	-	.29	.89	31.9
8	1.12±.47	-	-	.50	.89	29.8
9	.65±.82	-	-	.87	.54	3.4 n.s.
10	.66±.33	-	-	.36	.85	20.6
11	.89±.31	-	-	.33	.92	43.5
12	.68±.19	-	-	.20	.95	70.3
13	1.21±.37	-	-	.40	.94	55.8
14	.68±.13	-	-	.14	.97	138.0
15	.76±.37	-	-	.40	.87	22.1
16	1.11±.29	-	-	.30	.95	79.1
17	1.06±.34	-	-	.36	.93	51.2
Class 2						
18	.44±.20	-	-	.22	.87	24.7
19	1.14±.27	-	-	.29	.96	95.1
20	.47±.26	-	-	.28	.83	17.5
21	.79±.17	-	-	.18	.97	119.8
22	.90±.32	-	-	.34	.92	42.0
23	.84±.51	-	-	.55	.80	14.2
24	.54±.28	-	-	.30	.84	19.3
25	.93±.11	-	-	.12	.99	375.6
26	.82±.30	-	-	.32	.91	38.6
27	.63±.46	-	-	.49	.74	10.0
28	.48±.29	-	-	.45	.81	14.8
29	.74±.18	-	-	.19	.96	86.7
30	.89±.13	-	-	.13	.99	265.0
31	.31±.15	-	-	.16	.87	23.8
32	.60±.17	-	-	.18	.94	65.7
Means	.75±.29	-	-	.32	.89	64.7

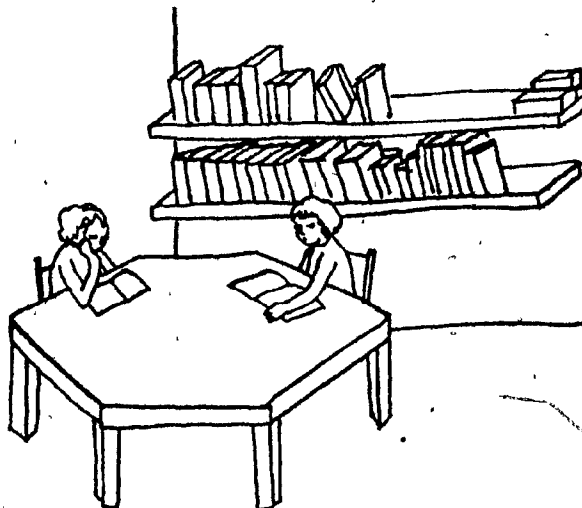
APPENDIX I

Samples of Picture Cards of Familiar School
Routines Used in Experiment.2B

Children getting dressed and ready to go home (Kindergarten).



Library period (grade 1).



APPENDIX J

Summary Tables of Best Fitting Regression Model for Each
Individual Subject for Duration Judgments
of Routines in Experiment 2B

Kindergarten

Subject	b(Time) ^a	Additional ^b Predictor	b ₂ ^c	Se	Multi- ple R	Cumula- ^d tive F
1	.25±.20	-	-	.39	.57	6.6
2	-.38±.62	Trial	.14	1.01	.63	4.4
3	.22±.15	-	-	.29	.64	9.7
4	.58±.21	-	-	.40	.85	35.3
5	.22±.44	-	-	.84	.28	1.2 ns
6	.31±.17	-	-	.32	.74	16.5
7	.10±.21	-	-	.40	.27	1.1 ns
8	.26±.25	-	-	.48	.52	5.2
9	-.03±.28	-	-	.54	.05	.0 ns
10	.05±.10	-	-	.19	.29	1.3 ns
11	.05±.25	-	-	.47	.11	.2 ns
12	.14±.19	-	-	.37	.39	2.5 ns
13	.03±.25	-	-	.48	.07	.1 ns
14	.30±.26	-	-	.51	.54	5.9
15	.49±.55	-	-	1.07	.45	3.6 ns
16	.14±.16	-	-	.31	.43	3.2 ns
17	.23±.17	-	-	.33	.62	8.6
18	.34±.29	-	-	.56	.56	6.3
19	.20±.20	-	-	.38	.50	4.7
20	.09±.31	-	-	.59	.17	.4 ns
21	.50±.18	-	-	.34	.85	37.0
22	.29±.17	Trial	-.04	.26	.84	15.8
23	-.03±.07	Trial	-.02	.10	.75	8.4
24	.25±.18	-	-	.34	.63	9.1
25	.17±.17	-	-	.33	.50	4.6
26	.26±.17	-	-	.32	.67	11.2
27	-	-	-	-	-	- ns
28	.07±.15	-	-	.28	.25	.9 ns
29	.62±.26	-	-	.51	.80	25.6
30	.18±.12	-	-	.24	.65	10.4
Means	.17±.23			.44	.50	8.3

In this and subsequent tables:

^aThe quantity following the (+) or (-) is the 95% confidence limit.

^bCut-off for significance level of F of additional predictor made conservative ($p \leq .01$).

^cb₂ refers to coefficient of additional predictor.

^dCut-off for significance level of cumulative F made $p \leq .05$.

APPENDIX J
(CONTINUED)

Grade 1

Subject	b(Time) ^a	Additional ^b Predictor	b ₂ ^c	Se	Multi- ple R	Cumula- ^d tive F
Class 1						
1	.33±.20	-	-	.37	.68	12.4
2	.22±.22	Trial, Last R	.04, -.29	.36, .27	.84	9.8
3	.18±.23	-	-	.41	.42	3.0 ns
4	.54±.31	-	-	.56	.70	13.4
5	.19±.17	-	-	.30	.54	5.9
6	.24±.19	-	-	.34	.58	7.2
7	.37±.29	-	-	.52	.60	7.7
8	.04±.24	-	-	.42	.10	.1 ns
9	.12±.15	-	-	.26	.43	3.2 ns
10	.53±.35	-	-	.63	.66	10.6
11	.49±.30	-	-	.54	.69	12.6
12	.32±.29	-	-	.52	.53	5.5
13	.07±.34	-	-	.61	.12	0.2 ns
14	.15±.27	-	-	.48	.31	1.5 ns
15	-.03±.15	-	-	.27	.10	.1 ns
16	.43±.41	-	-	.74	.52	5.2
17	-.07±.27	-	-	.48	.15	.3 ns
Class 2						
18	.20±.18	-	-	.33	.54	5.8
19	.55±.28	-	-	.51	.75	17.8
20	.23±.17	-	-	.30	.61	8.2
21	.35±.24	-	-	.43	.65	10.0
22	.45±.27	-	-	.49	.68	12.3
23	.49±.29	-	-	.51	.70	13.4
24	.11±.30	-	-	.55	.20	.6 ns
25	.24±.23	-	-	.42	.51	4.9
26	.42±.19	-	-	.35	.78	22.1
27	.55±.17	-	-	.31	.88	46.6
28	.38±.29	-	-	.51	.60	8.1
29	.36±.17	-	-	.30	.78	21.1
30	.32±.23	-	-	.40	.64	9.5
31	.33±.25	-	-	.44	.60	8.1
32	.49±.26	-	-	.46	.74	16.8
Means	.30±.25			.44	.55	9.5

APPENDIX K

"Time" Questionnaire Given to Elementary School Teachers
as Part of Pilot Study for Experiment 2C

Dear Teacher:

I am a McGill graduate student presently engaged in research which concerns "temporal disorders" in young children. This is a topic that psychologists, educational researchers and remedial teachers know very little about. What do you mean when we say that a child has difficulty understanding time? and more basic still: How does a child acquire a "sense" of time? Perhaps one of the reasons why we have but limited insight into the answers to these questions is that the child is left very much to his own resources when it comes to learning about time. We take it for granted that he will pick up a good deal of his knowledge of time without the assistance of the school curriculum. We do not single out "time" as a separate subject to be taught in school like arithmetic. As a result, children's problems in understanding time are not immediately obvious within the academic setting except as they may effect the learning of some complex skill. Although we have as yet only crude tests to measure what a child does and does not know about time, psychologists have found that many children with reading and language problems also demonstrate difficulties understanding time. The precise nature of these

difficulties is not clear. I hope that with your assistance, this research will clarify somewhat what is meant by the term "temporal disorder".

As I have already mentioned, the research thus far can tell us very little. It would seem to me then, that the logical place to begin seeking information is the classroom. You, as teachers, can be an invaluable aid by helping me to understand two important issues: First, what do teachers teach their pupils about time? What kind of information about time is systematically taught in the classroom and what incidental aspects of the school routine help children to learn about time? Second, what sorts of cues do teachers pick up from their pupils which lead them to suspect that a particular child is having problems understanding time? Your assistance in filling out the questionnaire that follows is greatly appreciated.

Thank you,

Lillian M. Esses
Department of Psychology
McGill University

PART I: What Do Teachers Teach Their Pupils About Time

The following are a list of temporal ("knowing about time") concepts and skills which are formally (systematic training) and informally (no systematic training but everyday aspects of school routine that encourage learning about time) taught by some teachers. It is highly likely that I have neglected to include a number of notions about time that teachers pass on to their pupils and therefore at the end of each section I have included a category marked "other" - please do not hesitate to make additions.

The categories have been constructed so as to apply to children from preschool to grade 3.

If a category is:

- (a) inappropriate for the age level children you teach mark with N/A (not applicable) to indicate that such is the case.
- (b) an appropriate one but no formal or informal training is given, mark with an "X".
- (c) an appropriate one and training is given, mark with a ✓ and describe formal and/or informal method of instruction.

N/A X ✓

description of method
of instructionTime Concepts

(1) rote skills

egs. days of week

months of year

seasons

holidays

other

(2) definite time words

egs. morning

afternoon

yesterday

tomorrow

today

next week

1921

10 years ago

day after tomorrow

other

(3) indefinite time words

egs. soon

right now

many years ago

after a while

<u>N/A</u>	<u>X</u>	<u>✓</u>	<u>description of method of instruction</u>
------------	----------	----------	---

in a minute

thousands of
years ago

other

(4) spatial representation
of time (measurement)

egs. calendar

time lines
(graphs)

clock time

other

(5) historical time

egs. prehistoric

- dinosaurs

- Roman Empire

- Egyptians

- World Wars

the future

- space travel

- science fiction

- living in the
sea

other

<u>N/A</u>	<u>X</u>	<u>✓</u>	<u>description of method of instruction</u>
------------	----------	----------	---

Perception of Time

(1) estimation of duration

egs. estimating and allotting time for completion of a task

estimating a given time interval (eg. one minute)

being able to estimate when a regular activity begins and ends

punctuality

awareness of time guides (eg. when recess, lunch, time to go home)

other

(2) sequencing

egs. before

after

ordinals

events in a story

events in a day

activities at school

series of designs

series of forms

other

description of method
of instruction

N/A X ✓

(3) rhythm

egs. comparing rhythms
(same or different)

tapping out a rhythm

completing a rhythmic sequence

dancing to a beat

other

(1) Does the school board delineate any specifics regarding what you should teach your pupils about time? If so, what are they? Do you follow these recommendations?

(2) Do you think it important to teach children in school the temporal concepts and skills outlined above? If so, why? If not, why not?

- (3) What, if any, additional temporal concepts and skills might you consider adding to your present curriculum?
- (4) Do you feel that teachers would benefit from additional suggestions regarding methods of teaching temporal concepts and skills?
- (5) Do you find it particularly difficult to teach any particular temporal concepts or skills? Explain.

PART II: What Cues Alert Teachers to Suspect that a Child
Has Difficulty Understanding Time?

- (1) How many children in your classroom do you suspect have difficulties understanding time?

Pupil A:

Pupil B:

Pupil C:

Pupil D:

Pupil E:

- (3) To what do you attribute his/her problem?

Pupil A:

Pupil B:

Pupil C:

Pupil D:

Pupil E:

- (4) Do any of these children demonstrate any difficulty acquiring academic skills such as arithmetic, writing, spelling, expressive language, reading, reading comprehension, fine motor skills (eg. using scissors), gross motor skills (eg. hopping)? and Is his/her academic difficulty mild, moderate or severe?

Pupil A:

Pupil B:

Pupil C:

Pupil D:

Pupil E:

- (5) Do you think that the temporal problem and the academic weakness are related? If so, in what way?

Pupil A:

Pupil B:

Pupil C:

Pupil D:

Pupil E:

- (6) Are any of these children difficult to control in the classroom? If so, describe.

Pupil A:

Pupil B:

Pupil C:

Pupil D:

Pupil E:

- (7) Do you think that the temporal and behavioral problem outlined above are related? If so, in what way?

Pupil A:

Pupil B:

Pupil C:

Pupil D:

Pupil E:

- (8) Are any of these children receiving assistance (egs. extra assignments, remedial work, tutoring, behavior modification, speech therapy)? Please describe.

Pupil A:

Pupil B:

Pupil C:

Pupil D:

Pupil E:

- (9) Do you think that children's difficulties in understanding time should be given more attention? If yes, why? If no, why not?

If yes, who should be giving these children special attention - parents? classroom teacher? remedial teacher?

- (10) Any suggestions for how we might better help children with temporal problems?

- (11) The gap between educational researcher and teacher is a vast one. Are there any particular questions regarding temporal learning in children that you would like to see investigated?

APPENDIX L

Numerical Memory Subtest from McCarthy Scales of
Children's Abilities used in Experiment 2C

<u>Forward Series</u>			<u>Score</u>
1	5-8	4-9	_____
2	6-9-2	5-8-3	_____
3	3-8-1-4	6-1-8-5	_____
4	4-1-6-9-2	9-4-1-8-3	_____
5	5-2-9-6-1-4	8-5-2-9-4-6	_____
6	8-6-3-5-2-9-1	5-3-8-2-1-9-6	_____
		Total	_____

APPENDIX M

Test of Memory Span for Unrelated Words
Used in Experiment 2C

1. a. hat, bank
b. man, coat
2. a. face, paint, clothes
b. bird, farm, voice
3. a. wind, arm, ball, night
b. tree, egg, king, hair
4. a. farm, trip, job, wall, plant
b. yard, floor, game, page, shape
5. a. milk, hole, field, box, room, foot
b. food, ring, plan, eye, moon, nine
6. a. ground, fire, leg, home, stick, fish, child
b. book, friend, train, hall, glass, roof, bag
7. a. girl, place, fruit, prince, march, road, shoe, word
b. night, mother, two, race, name, lake, grass, dance

Total Score

APPENDIX N

Oral Commissions Subtest from The Detroit Tests
of Learning Aptitude used in Experiment 2C

1. a. Show me the window. _____
b. Stand up straight. _____
2. a. Walk to the door; then bring me that book. _____
b. Walk to the window; then put this book on
a chair. _____
3. a. Put this pencil on the table; then open the
door; then fold your hands behind you. _____
b. Bring me that piece of paper; then close the
door; then stand on this line _____
4. a. Walk to the window; then tap the floor once
with your foot; then put this penny in my
hand; then tell me your name. _____
b. Open the door; then put a mark on this paper;
then bring me that book; then stand by the
window. _____
5. a. Bring me my watch; then clap your hands; then
sit on a chair; then point to the window; then
tell me your teacher's name. _____
b. Stand up; then turn around in a circle; then
touch your toes; then jump up in the air; then
stand next to me. _____

Total _____

APPENDIX O

Two Samples of Sequences Used in Test of Temporal
Sequencing Ability in Experiment 2C

Putting on shoes and socks.



APPENDIX O
(continued)

Making a sandwich.

