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AGE TRENDS IN CHILDREN'S TIMESHARING PERFORMANCE

by

Leann Elsie Traub Lipps

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Psychology)
in The University of Michigan
1975

Doctoral Committee:

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TO

DAVID

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CHAPTER I

INTRODUCTION

There is a good deal of evidence that we have a limited capacity for processing information, yet people are often able to perform two distinct activities concurrently. It is not unusual to carry on a conversation while driving or listen to music while reading. At least two factors appear to limit this ability to do two things at the same time. First, certain "biological bottlenecks" prevent, for example, looking two places simultaneously. The second factor is less well understood. Subjective experience tells us that while "easy" activities can be done at the same time, more "difficult" ones cannot.

What makes a particular task "easy" or "difficult" for an individual? Mackworth (1970) suggests that once an activity has been fully learned it no longer requires so much attention; it becomes "easier." To be sure, reading and walking are highly practiced activities for adults. This is not the case for children, who have less experience with the component skills necessary for the performance of various verbal and sensory-motor activities.

Studying man's limited ability to perform two or more tasks at the same time is as old as experimental psychology. Wundt (1874) reports a study using the dual task method to investigate this phenomenon, then referred to as the "division of attention." Many

studies of the dual task performance of adults can be found in the literature prior to the onset of behaviorism's domination of American psychology (see Geissler, 1909). During World War II interest in human performance under conditions of stress brought about a revival of the method,and quite recently there has been renewed interest in the use of timesharing as a method for measuring the attentional-capacity demands of mental processes (see Kerr, 1973, and Triggs, 1968 for reviews of the timesharing literature).

Generally, the results of such timesharing studies with adult subjects have shown that the concurrent performance of two activities produces decrements in one or both of the tasks relative to levels of performance attained on the tasks alone (McLeod, 1973; Welch, 1898). Further, several studies have shown that the decrements produced in one task are a function of the difficulty of the other (Johnston, Greenberg, Fisher & Martin, 1970; Kantowitz & Knight, 1974; Keele, 1967) and studies of the effects of learning on timesharing performance have generally shown that with practice on a task, the performance of a second timeshared task improves (Bahrick, Fitts & Noble, 1954; Bahrick & Shelly, 1958).

That children improve their performance on a variety of sensory-motor and verbal tasks with development and learning is well known, but there are almost no data that suggest how this improved performance in a single task setting might be related to changes in the performance of two such tasks concurrently. This experiment was

undertaken to determine the nature of developmental differences in the patterns of performance decrements produced by timesharing.

Relevant Developmental Studies

In the only study of its kind found in the literature, Hummer (1931) used a dual task method to compare the "distribution of attention" for subjects of different ages. Four age groups were used: 7- and 8-year-olds, 11- and 12-year-olds, 13- to 15-year-olds and adults of unspecified age. In the first part of the study subjects copied a set of signs in a prescribed order as fast as possible for 1 1/2 minutes. During the second part of the session subjects again copied signs while counting aloud the beats of a metronome for another 1 1/2 minute trial. She obtained performance measures on the copying task alone and timeshared and on the counting task in the timeshared condition only. From these measures she derived an "index of attention" by first forming a fraction for each task. For the writing task the timeshared score was placed over the alone score and in the counting task the timeshared score was placed over the maximum score. These two values were then multiplied to give the index. Values ranged from near zero to 1.0 for a subject who showed no performance decrements on the writing task in timesharing and had a perfect counting score. The obtained index value for the youngest group was .39. In order of increasing age, the values obtained for the three older groups were .51, .67, and .69, respectively.

From this evidence Hummer concludes, "the distribution of attention shows marked development up to age 15 but not beyond." Unfortunately, such a conclusion is based on very questionable data. Each subject performed in each condition only once. Failure to measure performance on the counting task alone may have affected the results for the age groups differentially, producing index values for the younger groups that were too low.

Evidence from studies of the effects of distraction on children's performance may provide some clues regarding the nature of developmental differences in timesharing performance. Research on the effects of distraction on performance can be viewed as examples of a dual task situation where the performance decrements produced in one task by a second task or distractor are studied. This second task may demand either an overt or a covert response and the subject may or may not receive explicit instructions about the distracting task. Most studies of the effects of distraction on children's performance of various tasks have not found developmental differences in the effects of a distractor task on task performance. Hagen (1967) administered a task that required remembering the spatial position of pictures to 1st-, 3rd-, 5th-, and 7th-graders. He found that the addition of a vigilance-type task requiring a tapping response to piano notes produced equivalent decrements in the performance of the memory task for all age groups. Data on the performance of the vigilance task were not reported. Several other studies have found no differences in

the effects of a distracting task on primary task performance as a function of age (Maccoby & Hagen, 1965; Obata, Morita & Matsumoto, 1933; Poyntz, 1933).

One difficulty in interpreting studies of distraction within a dual task framework is that even in cases where the distractor task requires an explicit response that can be measured, performance on that task is not usually reported. An exception is found in a recent study by Doyle (1973). In a dichotic listening task she tested for the retention of words in both the shadowed and the "distracting" messages in addition to measuring shadowing performance. Eight, 11-, and 14-year-olds were instructed to "listen, repeat and try to remember what you hear" from one of the two messages. In contrast to the other studies of distraction reported, a comparison of the distraction and no distraction conditions showed that the presence of the second message produced significant decrements in the performance of the younger but not the older children. The retention of words from the shadowed message increased with age while the retention of the words in the distracting message remained constant over age. Studies of distraction do not provide clear evidence suggesting the nature of developmental differences in the patterns of performance decrements obtained in timesharing. Information about the effects of the first task on the secondary "distracting" task is essential in any analysis of the effects of timesharing; performance measures must be obtained for each task, in both an alone and a timeshared condition.

Timesharing and the Secondary Task Technique

Bahrick, Noble and Fitts (1954), in a study based on the notion that with practice certain tasks become less susceptible to interference, investigated the possibility that the performance on a subsidiary task could serve to reveal learning on a task not revealed by conventional measures. Results of this and a later study (Bahrick & Shelly, 1958) showed that performance on a second task later in practice of the first task was superior to the timeshared performance. on the second task earlier in practice. They suggested that the aspect of learning which makes performance on one task more compatible with another concurrent activity may be

> "...particularly characteristic of the later stages of learning certain tasks and secondary task performance may be a useful way of measuring overlearning under conditions of extended practice."

These studies are examples of the secondary task technique. Performance measures on a second task in timesharing are used to provide information about tasks not revealed by conventional measures of the performance, i.e., the effects of overlearning after the performance on a task has reached asymptotic levels (Bahrick, Noble & Fitts, 1954), or more recently as a measure of information processing difficulty or demand (MacLeod, 1973; Posner & Keele, 1970). In some studies using the secondary task technique subjects are given explicit instructions about task priorities while in others they are not. In the second case, studies of timesharing using the technique can be distinguished from other timesharing studies only at the level of analysis and

interpretation of the data. The results of these studies have generally shown that secondary task decrements are a function of the difficulty or complexity of the first task, where difficulty is often defined by an error measure on the first task in a baseline condition (Johnston, Greenberg, Fisher & Martin, 1970) or complexity in bits of information (Kantowitz & Knight, 1973). This basic finding has been replicated using various tasks: a Fitts' tapping task at two levels of complexity (Kantowitz & Knight, 1973), memory tasks (MacLeod, 1973), and same-different letter matching (Posner & Bois, 1971); and using tracking (MacLeod, 1973) as well as other secondary tasks, including simple reaction time (Posner & Bois, 1971) and digit naming (Kantowitz & Knight, 1973).

The secondary task technique will be applied in the present study in examining the data for developmental trends in the relationship between task difficulty and subsidiary task decrements in timesharing. An auditory matching task is used as the first task. The difficulty of the task is varied by altering the basis of the same-different judgments. In the first condition, pairs are matched on the basis of physical identity. In the second, category identity is the basis of the judgments. A one-dimensional compensatory tracking task serves as the subsidiary task. In addition to the use of the secondary task technique, the effects of tracking on matching task performance will be examined.

Effects of Instructions on Timesharing Performance

Several investigators have mentioned the importance of giving subjects clear and explicit instructions about the relative importance of the tasks to be timeshared (Geissler, 1909; Triggs, 1968), but the effects of instructions on timesharing performance have been largely ignored. In one study that did investigate the impact of verbal instructions on timesharing, Murdock (1965) found that giving instructions to adults to "concentrate primarily on" one or the other of the tasks produced distinct differences in the expected direction in the serial position curves of the timeshared memory task for the two instructional conditions. The timeshared tasks used were remembering a list of words and a card sorting task. The data were interpreted as evidence for subjects "trading off" the two tasks, i.e., improving on the "concentrate primarily on" task while allowing larger decrements on the non-emphasized task. In a later study, Murdock (1969) cautioned against his earlier interpretation of the results and stated that they may have been an artifact of the two particular tasks used.

Thus there appears to be some equivocal evidence that adults are able to use verbal instructions to modify their timesharing performance in the instructed direction. There are no data on whether children can use such instructions. The present study investigates this question and explores the possibility that there are developmental differences in the impact of verbal instructions on the distribution of decrements produced by timesharing. It is

expected that the instructional factor should have a greater effect on the performance of the older children, who will be more able to use the instructions to alter their timesharing performance in the instructed manner.

Limited Capacity Models of Attention

In recent information processing models man has been conceptualized as having a limited general capacity for processing information (Kahneman, 1973; Moray, 1967). This general capacity is allocated to processes and activities in a flexible manner. All mental processes, whether perceptual-motor or coding-transformational, require the allocation of limited capacity. If an activity can be performed with the allocation of less than the total capacity for mental effort, the spare capacity can be allocated to other tasks or activities. Successful concurrent performance of a second activity is interpreted within these models as indicating that the individual has allocated spare capacity to the performance of the second task. The addition of a subsidiary task can thus be used as a diagnostic tool for evaluating the demands for attentional capacity made by a primary activity.

In a second contemporary model, Keele (1973) states that some but not all mental operations require space in a limited capacity mechanism. Decrements in timesharing appear when two mental operations simultaneously require the mechanism. While certain mental operations

always require the mechanism, others never do. Operations of the second type may thus proceed in parallel without interference. In general, processes of response organization tend to make greater demands on central processing space causing greater interference than perceptual processes.

Although these limited capacity models of attention have not addressed the general question of how attentional-capacity demands of various tasks might differ with development, these models can provide alternative interpretations of the data of the present study. Within Kahneman's (1973) view, developmental differences in patterns of decrements in timesharing can be interpreted as reflecting differences in the relative demands made by the tasks for limited capacity. Using Keele's (1973) formulation, developmental differences in patterns of timesharing decrements reflect different patterns of interfering subprocesses. The data of the present study will not provide support for one model to the exclusion of the other.

In summary, the study to be reported is an investigation of the development of children's timesharing abilities. The secondary task technique will be applied in interpreting the performance of the matching tasks, both alone and timeshared. It is expected that the performance of both types of matching tasks should produce proportionately greater relative decrements in the secondary task performance of the younger subjects, and that the category matching task should produce greater relative decrements in the performance of the

tracking task for children in all three age groups. The impact of verbal instructions on the locus of performance decrements in time-sharing will be examined with the expectation that older children will be more able to use instructions to modify their timesharing performance.

CHAPTER II

METHOD

Subjects

The subjects were 60 boys, 20 each from the first-, fourth-, and seventh grades. The mean ages for the three age groups were 6 yrs. 11 mo., 10 yrs. 1 mo., and 13 yrs. 1 mo., respectively. All of the children were white, middle class and attended elementary school in Whitmore Lake, Michigan. All of the subjects had vision and hearing within the normal range. Two subjects from the youngest group were replaced, one for failure to perform one task and the other for failure to follow instructions. Each of the 20 subjects within an age group was randomly assigned to one of the two instructional conditions.

Apparatus and Materials

The experimental tasks selected for timesharing were a forced paced auditory matching task which was designed to have two levels of difficulty and a compensatory one dimensional tracking task.

Auditory Matching Tasks

The stimuli for the matching tasks were three-, four-, and five-letter words selected from Thorndike and Lorge (1944) frequencies of 1-AA. Fifty-eight nouns were selected. Each noun could be classified as a member of one of four categories (12-16 nouns per category):

animals, parts of the body, clothing, and food. The stimulus words appear in Table 1 and the stimulus lists are presented in Appendix I. The two levels of the task were generated by altering the basis on which the matches were made. In the physical identity condition (A_w) judgments were based on phonemic identity, "Are the two words in the pair the same word?"; in category matching (A_c) judgments were based on category identity, "Are the two words the same kind of word?". For the A_w condition the stimulus pairs were constructed using words from all four categories. Half of the "different" pairs came from within a category and half from different categories, while the "same" pairs all came from within the same category. In the A_c condition the "different" pair words were selected from different categories and the "same" pair words came from within a category. The order of the pairs was randomly determined in all lists, with the restriction that not more than three "same" or "different" pairs occurred in succession. Within a stimulus list no word appeared in more than three pairs. Fifteen "same" and 15 "different" pairs appeared in each stimulus list.

In both types of matching task the stimulus pairs were presented at a rate of one pair every two seconds; thirty pairs were presented during each one minute trial. Six different stimulus lists were constructed for use in the A_w condition and nine stimulus lists for the A_c condition so that no child heard the same stimulus list more than once. All the stimulus materials were recorded in the same

TABLE 1

STIMULUS WORDS USED IN AUDITORY MATCHING

Category	Word	Category	Word
Animal	cat	Part of Body	arm
	dog		leg
	fox		toe
	pig**		chin
	bird*		face
	deer*		head
	duck*		nose
	fish		skin
	goat		mouth
	mouse		cheek
	sheep*		brain
	frog*		chest
	swan		thigh
	bug		wrist
			foot
			neck
Clothing	cap	Food	stew
	tie		jam
	belt		egg
	coat		nut
	shoe		pie
	suit		cake
	dress		milk
	skirt		meat
	scarf		soup
			beef
			bread
			cream
			grape
			peach
			fudge
			steak

*not paired with food category words in A_c condition to prevent ambiguity

female voice using a Sony Model 500T tape recorder. The stimuli were presented to the children binaurally through headphones. A cassette recorder (Sony Model TC-80) was used to record all of the subjects' responses to the stimulus lists of the matching tasks. The timing of the verbal responses was recorded on the event recorder channel of a Bausch and Lomb Lab Recorder (Model VOM-5) which was connected to the microphone attached to the headphones worn by the child through a voice operated relay.

Tracking Task

A Simplified Electronic Tracking Apparatus (SETA) of the type described by Gain and Fitts (1959a) was connected to a Tektronix Type 503 cathode ray oscilloscope with a 15 cm display screen. In performing the tracking task the child manipulated a control knob with his preferred hand. The SETA was housed in two cabinets: an experimenter's console that recorded the subjects' integrated absolute error score (IAE) in arbitrary units for each one minute trial, and the subject's error (the difference between the signal input "problem" and the subject's output "solution") on a zero center voltmeter with a range of $\pm$12.5 volts, located on the front panel. The subject's console was hidden by a plywood panel and the error was displayed on the cathode ray tube (CRT) of the oscilloscope as a moving horizontal cursor. The subject's solution output was recorded on the analog channel of the Bausch and Lomb Lab Recorder Model VOM-5. One complete cycle of the signal input problem is shown in Figure 1. The

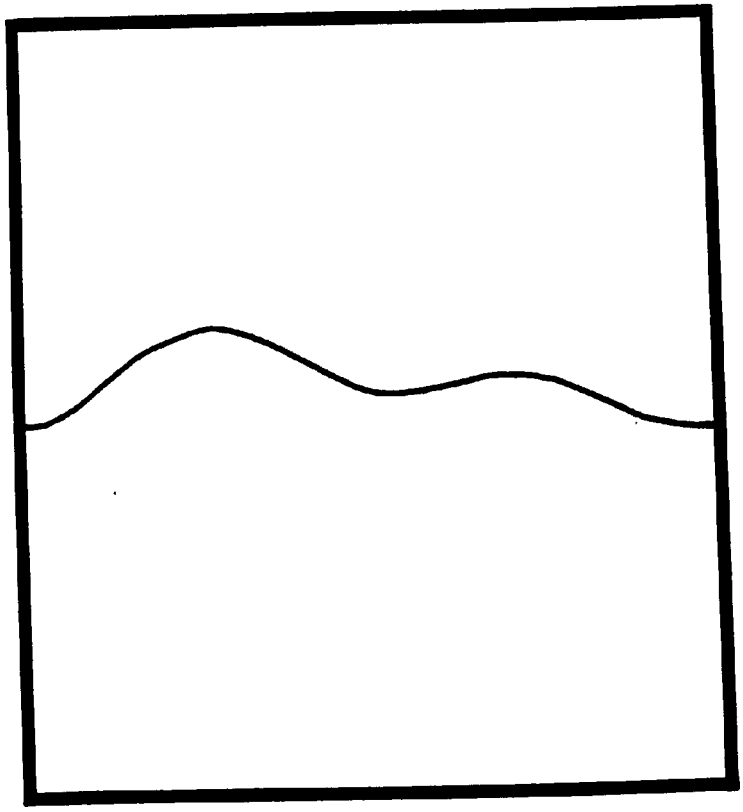


Fig. 1. Tracking signal input.

subject was seated facing the CRT display which appeared in the 17.5 cm x 19.0 cm rectangular opening of a large plywood panel. The CRT display was paced approximately 45 cm from the subject. The height of the chair used was varied so that the display was near eye level for all subjects. The experimenter was seated to the left of the subject.

Procedure

The experiment was conducted during regular school hours in a trailer parked outside the school. All of the boys were seen individually by the same female experimenter for one session about one hour in length. Within the session all the children were given the same ordering of the tasks. A plan of the experimental session appears in Table 2.

All subjects initially received ten tracking trials prior to the introduction of the auditory task. Trials one through seven were classified as practice trials while trials eight through ten constituted Block 1 (Tr_1). Each tracking trial was one minute in length and the intertrial interval was approximately 15 sec. During this interval the subject was told his error score for the preceding trial. There were no regularly scheduled rest periods during this part of the session but if the subject appeared tired or inattentive or if his hand seemed to fatigue quickly, brief rests were given as necessary.

After the initial ten tracking trials the physical matching (A_w) condition was introduced. First, three one minute trials were presented

TABLE 2

PLAN OF EXPERIMENTAL SESSION

Performance Condition and Block Number	Task	
	Tracking	Auditory Matching
1 Alone (Tr)	Practice	
2 Alone (Tr)	Practice	
3 Alone (Tr)	Tr_1	
4 Alone (A_w)		A_w - Physical Matching
5 Timeshared	Tr +	A_w
6 Alone (tr)	Tr_2	
7 Alone (A_c)		A_c - Category Matching
8 Timeshared	Tr +	A_c
9 Alone (Tr)	Tr_3	
---------- Instructions ----------		
10 Timeshared	Tr +	A_c
11 Alone (Tr)	Tr_4	

alone; three (A_w) trials were then given timeshared with the tracking task ($Tr+A_w$), followed by three tracking trials alone (Tr_2). Tracking alone blocks were interspersed in this manner in order to obtain a running baseline. Performance on timeshared blocks was always compared with the immediately previous alone blocks. In this way, any practice effects operated in the direction of reducing differences between the alone and timeshared performance conditions. After a two minute rest interval the category matching (A_c) condition was presented alone for three trials, followed by three trials timeshared with tracking ($Tr+A_c$). In both the timeshared blocks ($Tr+A_w$) and ($Tr+A_c$), the tracking task and the matching tasks were presented as equally important and the children were told to perform both tasks as well as possible. A complete set of the instructions used in the experiment appear in Appendix II. Two minute rest intervals were given after the Tr_1, Tr_2, and Tr_3 blocks. During these two minute intervals the subject was encouraged to leave his seat and move about. All other intervals between trial blocks were approximately thirty seconds long, and the two intertrial intervals within all blocks were about ten seconds in length.

Following the Tr_3 block the instructions designed to alter time-sharing performance were administered. At each age level the children were randomly assigned to either the tracking primary (Tr_{pr}) or the auditory primary (A_{pr}) condition. The instructions were given in as standardized a form as possible and appear in Appendix II.

Essentially, either the tracking task or the auditory task was emphasized in three ways. First, it was designated as most important; second, the children were told to pay most attention to it; and third, they were told to improve their performance on the primary task in comparison with the previous timeshared block of the "both" condition. After the administration of the instructions the children performed another block of $Tr+A_c$ trials. Three final tracking trials followed the $Tr+A_c$ block. At the end of the session the children were questioned about how they were able to do two things at once and were encouraged to introspect about their experience.

CHAPTER III

RESULTS

Tracking Task

The mean integrated absolute error (IAE) scores for Trials 2-22 for each age group appear in Figure 2. The performance levels of the three groups are ordered as a function of age with the youngest children showing the largest error scores. The first tracking trial was omitted from the analyses; although some children initially seemed to understand the instructions for the task, their performance on the first trial indicated a lack of understanding. These children were given further instructions and assistance as necessary during Trial one in turning the control knob to move their dot toward the target dot. Only one subject from the youngest group was eliminated for failure to perform the task correctly after the additional practice and instruction given during Trial one.

Because the baseline levels of performance on the tracking task alone were very different for the three age groups, a logarithmic transformation was done on the IAE scores for each subject. The raw scores for each child for Trials 1-28 appear in Appendix III. The transformed scores were used in all subsequent analyses of the tracking data but in presenting aspects of the results in graphic and tabular form both IAE and the lnIAE scores are shown. The lnIAE scores for the three age groups for Trials 2-22 appear in Figure 3.

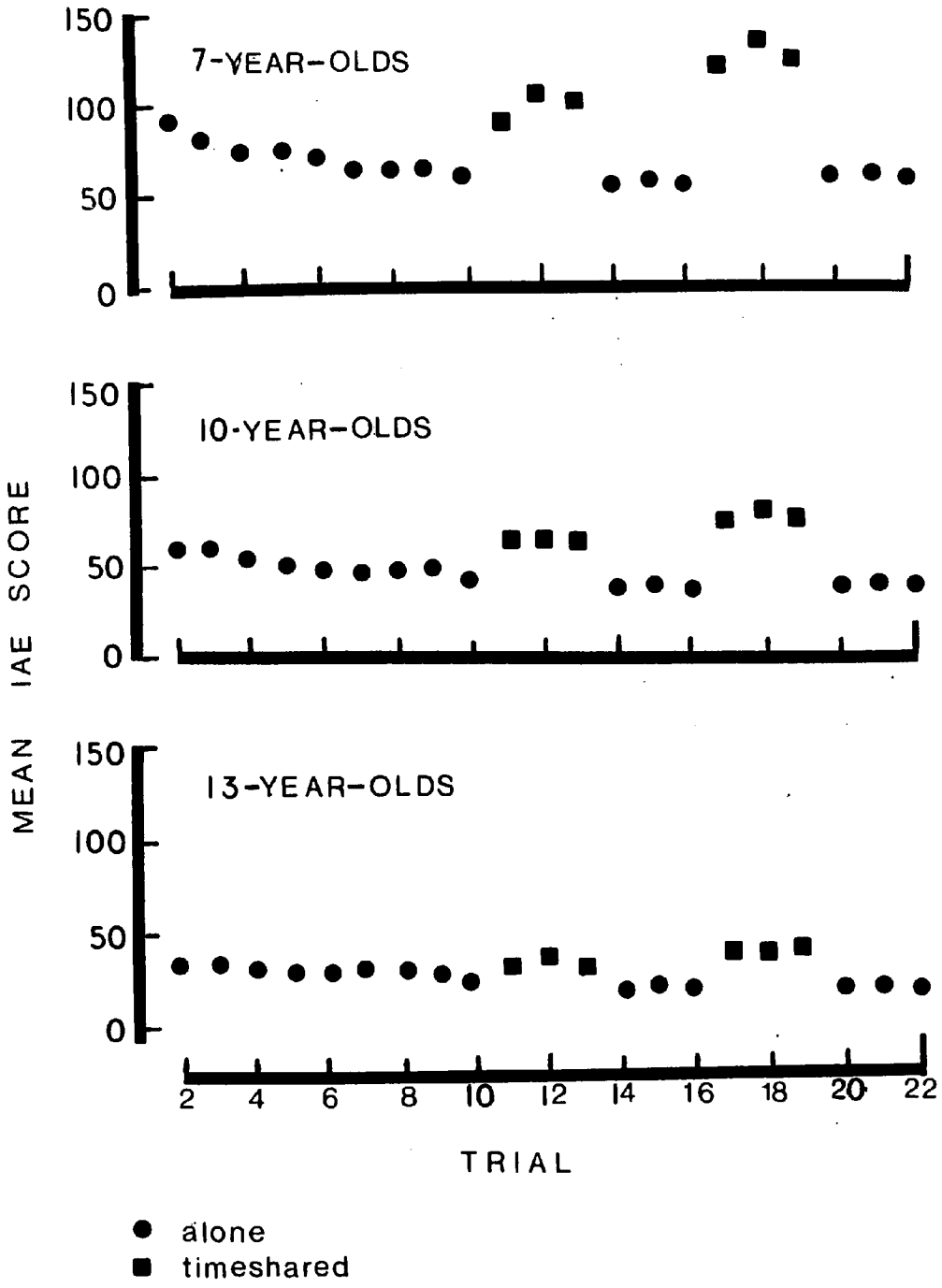


Fig. 2. Mean tracking score in IAE units for Trials 2-22.

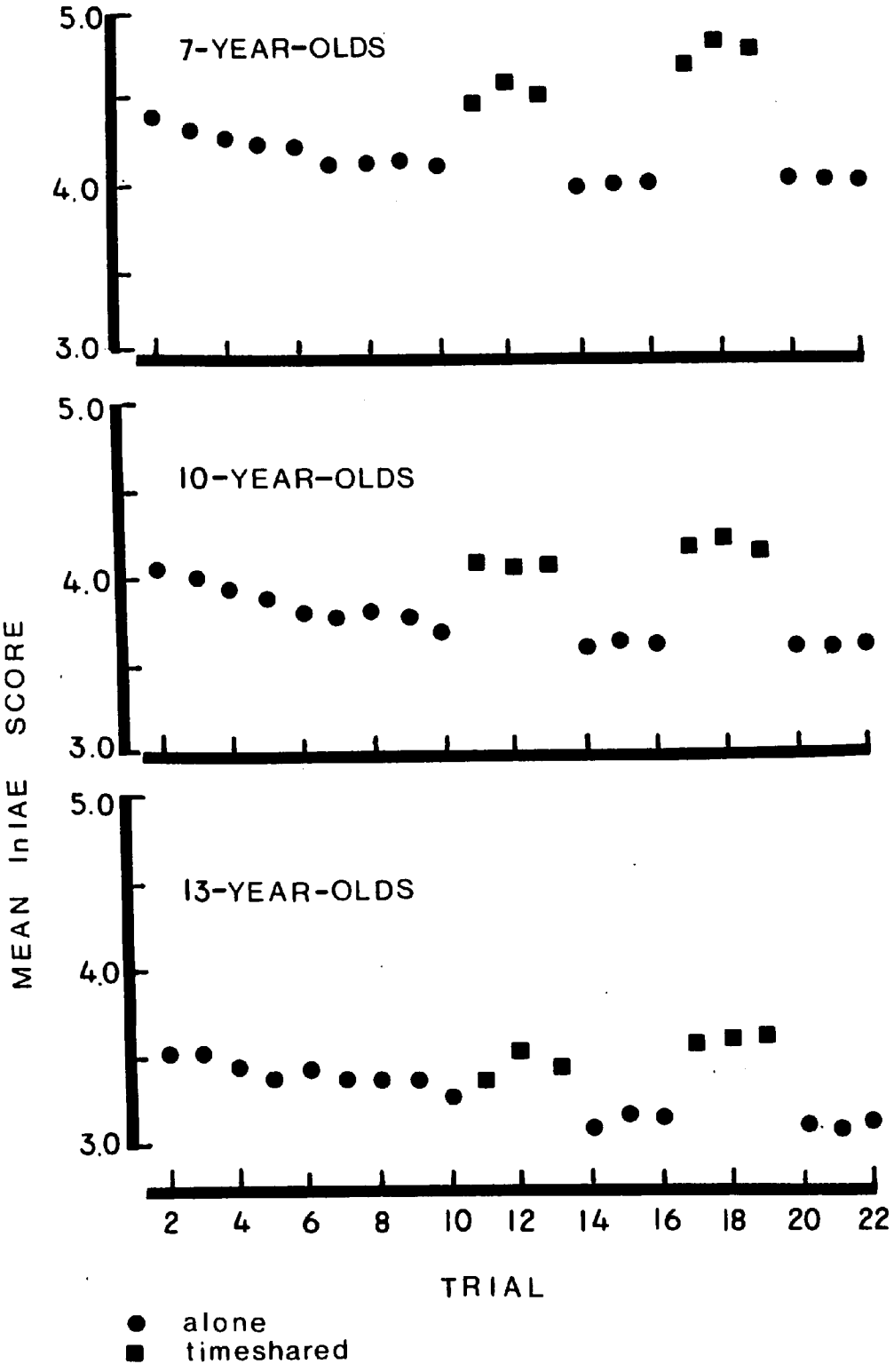


Fig. 3. Mean tracking score in lnIAE units for Trials 2-22.

The ln transform makes it possible to compare performance decrements produced by timesharing relative to each group's baseline level; statements are made about proportions rather than absolute decrements found in timesharing relative to level of performance on the tracking task alone: $\ln(Tr+A_w)-\ln(Tr) = \ln(Tr+A_w/Tr)$. Because the transformed lnIAE scores are used in generating the decrement scores, an increase in error score from 80 to 100 IAE units is equivalent to one from 20 to 25 IAE units as the ratios of the timeshared and alone baseline scores are the same. It should be noted that the units of the IAE scale are arbitrary and that various monotonic transforms are often performed on this measure for clarity or ease of presentation. The ln transform eliminated the heterogeneity of variances for the three age groups that existed in the IAE data.

The major focus of the experiment was the question of developmental differences in timesharing performance. To determine whether significantly greater proportional decrements were found in the timesharing conditions for the younger than the older subjects, decrement scores were obtained for each subject. The total lnIAE score obtained on the previous tracking alone block was subtracted from the total timeshared block lnIAE score for each type of matching task: $D_w = (Tr+A_w) - (Tr_1)$; $P_c(Tr+A_c) - (Tr_2)$. A 2 x 3 analysis of variance for repeated measures was performed on the obtained D_w and D_c scores with type of match as the repeated measure and age as the second factor. Cell means for both the lnIAE and the IAE decrement scores appear in Table 3. As expected, the main effect of age was significant,

TABLE 3

MEAN TRACKING IAE DECREMENT SCORES
(lnIAE UNITS IN PARENTHESES.)

Age Group	Timesharing Block: Tracking + Physical Matching $(Tr+A_w)-(Tr_1)$	Timesharing Block: Tracking + Category Matching $(Tr+A_c)-(Tr_2)$
7-year-olds	35.3 (1.25)	67.7 (2.31)
10-year-olds	17.8 (.90)	35.2 (1.73)
13-year-olds	4.51 (.35)	15.25 (1.31)

($F(2,57) = 7.98$; $p < .01$), with the youngest group showing the greatest proportional decrements in tracking performance (see Fig. 4). The main effect of type of match was also highly significant ($F(1,57) = 72.37$; $p < .001$), with category matching producing greater decrements in tracking performance than physical matching for all age groups. The Age x Type of Match interaction was not significant ($F(2,57) < 1.0$). Individual Scheffé comparisons were performed for each type of auditory match. For the physical matching D_w scores the 10 years-13 years pair ($t(20) = 2.07$; $p < .05$) was significant while the 7 years-10 years pair was not. Comparisons for the D_c scores indicated that the 7 years-10 years pair ($t(20) = 2.01$; $p < .05$) was significant, while the 10 years-13 years pair was not.

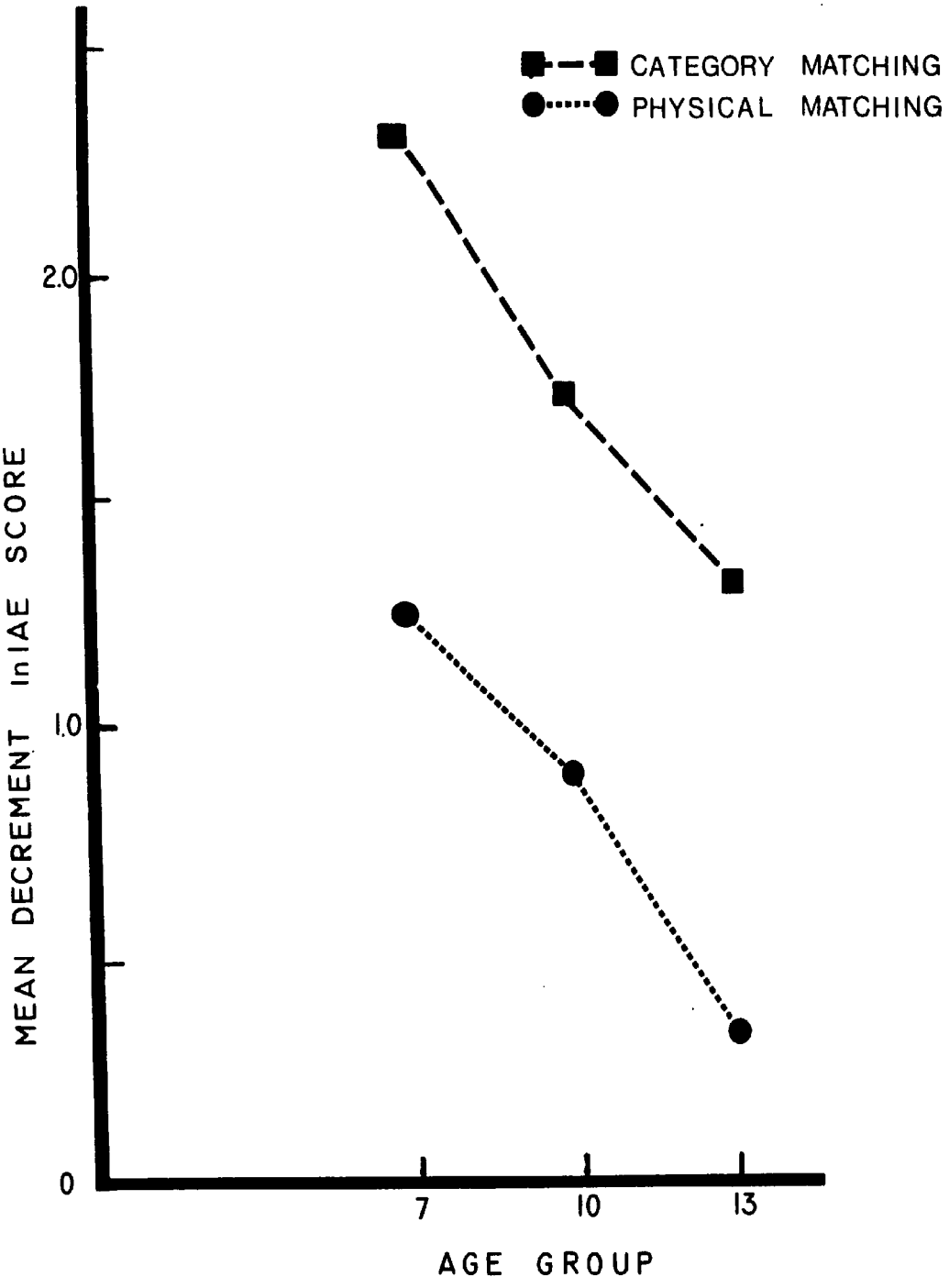


Fig. 4. Tracking decrement scores produced by timesharing for physical and category matching.

As shown in Figure 5, all three age groups improved their performance on the tracking task during Trials 2-10. To determine whether the acquisition rate differed for the three groups, a least squares linear regression was done using the lnIAE scores for each subject on Trials 2-10. A slope parameter was obtained for each subject and a one way analysis of variance with age as a factor was performed on the slope scores. The results of the analysis were not significant ($F(2,57) < 1.0$). Although the initial levels of performance on the task were very different for the three age groups, their acquisition rates as reflected by the mean slope scores for each group did not differ with age. The obtained best fitting regression line is plotted in Figure 5 for each age group.

To examine the age differences in the error scores for the tracking alone blocks, one way analyses of variance with age as a factor were done on the total lnIAE scores for the Tr_1 and Tr_2 blocks. The lnIAE and IAE scores for the Tr_1 and Tr_2 alone blocks and the timeshared $Tr+A_w$ and $Tr+A_c$ blocks appear in Table 4. The results of both analyses were highly significant: For the Tr_1 block, $F(2,57) = 39.30$; $p < .001$; Scheffé pairwise comparisons indicated that both the 7-years,10-years ($t(20) = 4.20$) and 10-years,13-years ($t(20) = 4.66$) pairs were significant at the $p < .001$ level. For the Tr_2 block, $F(2,57) = 37.16$; $p < .001$. The Scheffé comparisons indicated that the three groups were significantly different (7-years,10-years ($t(20) = 4.08$; $p < .001$; 10-years,13-years, ($t(20) = 4.52$). Corresponding analyses of the Tr_3 and Tr_4 blocks were also significant

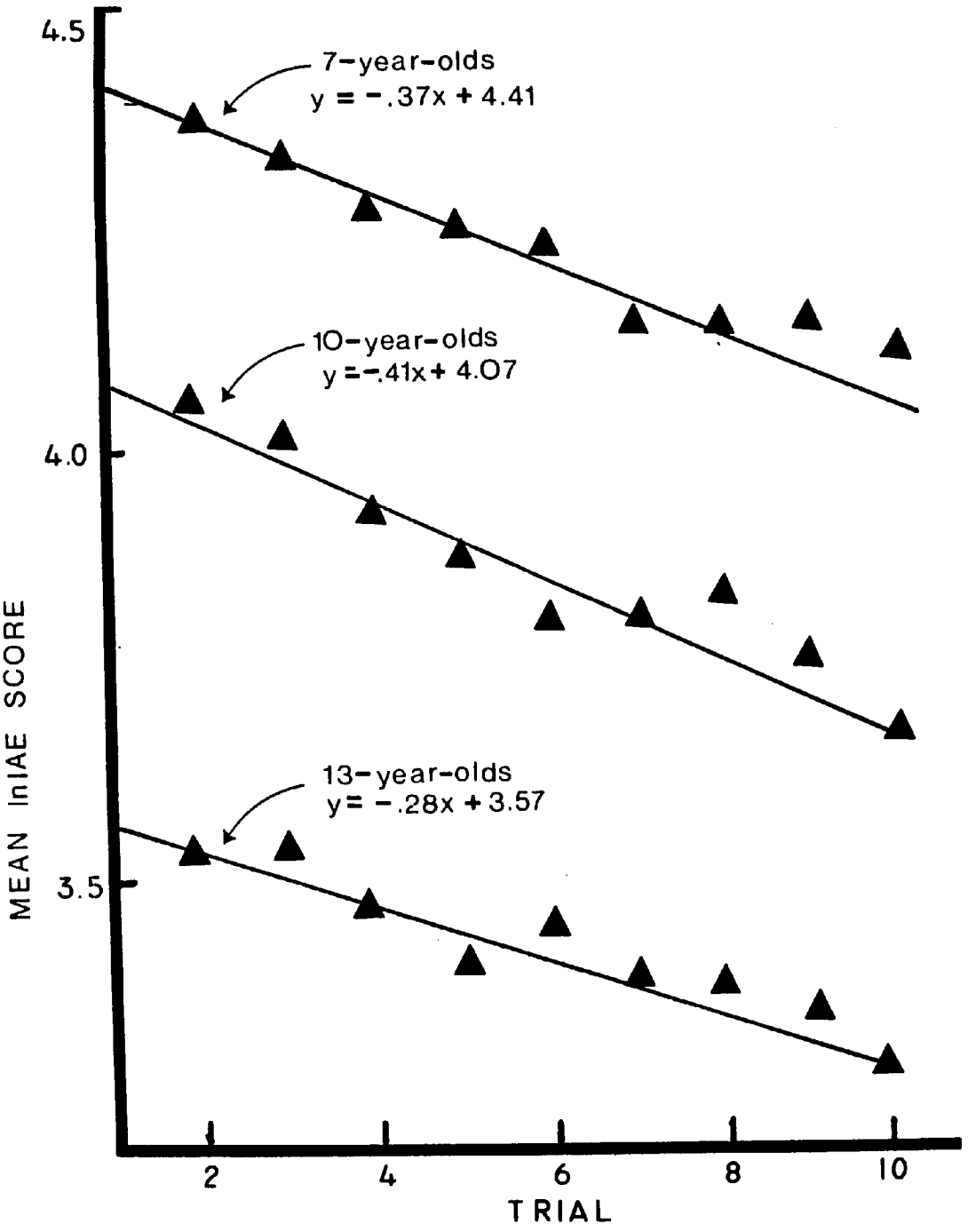


Fig. 5. Tracking error scores for Trials 2-10 and best fitting linear regression line.

at the $p < .001$ level. Although the results have shown that the age levels did not differ in acquisition rate, the older children showed markedly better performance on the tracking task at all stages of practice.

As can be seen in Table 4, the level of performance in both the $Tr+A_W$ and $Tr+A_C$ timesharing conditions also differs for the three age groups. The results of one way analyses of variance on the lnIAE scores for both timesharing conditions indicated that error scores were directly related to age, with the youngest subjects showing the largest error scores. The analysis for the $Tr+A_W$ condition was highly significant ($F(2,57) = 48.00$; $p < .001$). Scheffe comparisons showed both the 7-years,10-years ($t(20) = 4.41$) and 10-years,13-years ($t(20) = 5.37$) pairs were significantly different at the $p < .001$ level. Similar results were obtained in the analysis of the $Tr+A_C$ data: $F(2,57) = 40.6$; $p < .001$ and both the 7-years,10-years ($t(20) = 4.52$; $p < .001$) and 10-years,13-years ($t(20) = 4.49$; $p < .001$) Scheffé pairwise comparisons were significant.

The results of the analyses of the tracking error scores have shown that level of tracking performance is directly related to age. However, it was possible to match 16 pairs of subjects from different age groups on the basis of their tracking performance on the Tr_1 block: One group of eight ten-year-olds was matched with eight seven-year-olds and another group of eight ten-year-olds was matched with eight 13-year-olds. The subjects were matched on their tracking

TABLE 4

MEAN TOTAL TRACKING ERROR SCORES FOR TRACKING ALONE AND TIMESHARED BLOCKS IN IAE AND lnIAE UNITS. (lnIAE UNITS IN PARENTHESES.)

Age Group	Trial Block			
	Tr_1	$Tr+A_w$	Tr_2	$Tr+A_c$
7-year-olds	66.0 (12.31)	101.3 (13.64)	59.1 (12.03)	126.8 (14.34)
10-year-olds	44.7 (11.26)	62.5 (12.16)	38.5 (10.78)	73.7 (12.52)
13-year-olds	29.4 (10.01)	33.9 (10.37)	23.7 (9.40)	39.0 (10.71)

scores in order to gain some information about the obtained differences in timesharing decrements: were they attributable to age per se or were the effects primarily a function of the level of performance on the tracking tasks? T-tests for matched groups were performed on the lnIAE scores for the Tr_2, $Tr+A_w$, $Tr+A_c$ blocks and on the obtained D_w and D_c decrement scores. The analyses were done for the two age contrasts separately and for the 16 pairs combined in a younger-older contrast. None of the t statistics were significant, although the decrement scores for the younger subjects are slightly greater than for the older children. If subjects show equal performance on the

task alone, then no significant age differences are found in the performance decrements produced by timesharing either physical or category matching.

Intratask correlation matrices are presented in Table 5 for the total sample and for each age group. The lnIAE scores for each block were correlated with each of the other trial blocks. These correlations are generally highly positive, and all but four within the three age group matrices are significant at the .05 level. This suggests that for the total sample and within an age group a child tended to maintain his position within the group with respect to tracking performance; a child who did well on the tracking task when done alone as indicated by a low error score tended to do well on the timeshared tracking trials for both types of auditory matching task.

Auditory Matching Tasks

In analyzing the data for the physical and category matching task an error was defined as an incorrect response, i.e., saying "yes" when "no" was correct or as an omission. The group means for errors obtained on the physical and category matching tasks both performed alone and timeshared are presented in Table 6. The error data for individual subjects appear in Appendix III with the tracking scores for each trial. Errors were the primary dependent measure of matching performance but several analyses were performed on the omission data.

One-way analyses of variance with age as a factor were done on the error scores for each of the physical and category matching blocks

TABLE 5

TRACKING TASK INTERCORRELATIONS FOR THE TOTAL SAMPLE AND WITHIN EACH AGE GROUP

Performance Condition	Tr_1	$Tr+A_w$	Tr_2	$Tr+A_c$
Tr_1	---			
$Tr+A_w$	.85**	---		
Tr_2	.90**	.90**	---	
$Tr+A_c$	.81**	.93**	.88**	---
		7-year-olds		
Tr_1	---			
$Tr+A_w$	.70**	---		
Tr_2	.86**	.77**	---	
$Tr+A_c$	.69**	.82**	.69**	---
		10-year-olds		
Tr_1	---			
$Tr+A_w$	.52*	---		
Tr_2	.62*	.72*	---	
$Tr+A_c$	.57**	.90**	.83**	---
		13-year-olds		
Tr_1	---			
$Tr+A_w$	.70**	---		
Tr_2	.76**	.79**	---	
$Tr+A_c$	.49*	.78**	.68**	---

TABLE 6

MEAN TOTAL ERROR SCORES ON AUDITORY MATCHING TASKS ALONE AND TIMESHARED

Age Group	Trial Block			
	A_w	$Tr+A_w$	A_c	$Tr+A_c$
7-year-olds	16.3	22.6	44.8	54.1
10-year-olds	5.25	11.4	30.4	38.6
13-year-olds	3.9	7.0	15.85	20.25

alone and timeshared: A_w, $Tr+A_w$, A_c and $Tr+A_c$. In all four analyses the effect of age was highly significant: A_w, $F(2,57) = 26.42$, $p < .001$; $Tr+A_w$, $F(2,57) = 22.73$, $p < .001$; A_c, $F(2,57) = 37.78$, $p < .001$; and $Tr+A_c$, $F(2,57) = 45.63$, $p < .001$. All Scheffé comparisons were significant in each analysis at at least the $p < .05$ level. Box tests for homogeniety of variance were not significant for any of the auditory matching block scores.

To determine the effects of timesharing on auditory matching performance, two two-way analyses of variance for repeated measures were done on the error scores with performance condition (alone or timeshared) and age as factors. The first analysis used the scores for the physical matching blocks, A_w and $Tr+A_w$, and the second the scores on the A_c and $Tr+A_c$ blocks. These error scores are shown for each

age group in Figure 6. The main effect of performance condition was significant in both analyses: for physical matching, $F(1,57) = 21.40$, $p < .001$, and for category matching, $F(1,57) = 34.4$, $p < .001$. The effect of age was significant in both analyses reflecting the results of the one-way analyses already presented. The Performance Condition x Age interaction did not reach significance in either analysis. Timesharing did not produce decrements in the performance of the matching tasks which differed as a function of age, in contrast to the age differences timesharing produced in tracking performance. The mean decrement scores for the $Tr+A_W$ and $Tr+A_C$ blocks appear in Table 7.

TABLE 7

MEAN AUDITORY TASK DECREMENT SCORES
PRODUCED BY TIMESHARING

Age Group	Timesharing Block	
	Tracking + Physical Matching $(Tr+A_W) - (A_W)$	Tracking + Category Matching $(Tr+A_C) - (A_C)$
7-year-olds	6.3	9.4
10-year-olds	6.2	8.3
13-year-olds	3.1	4.4

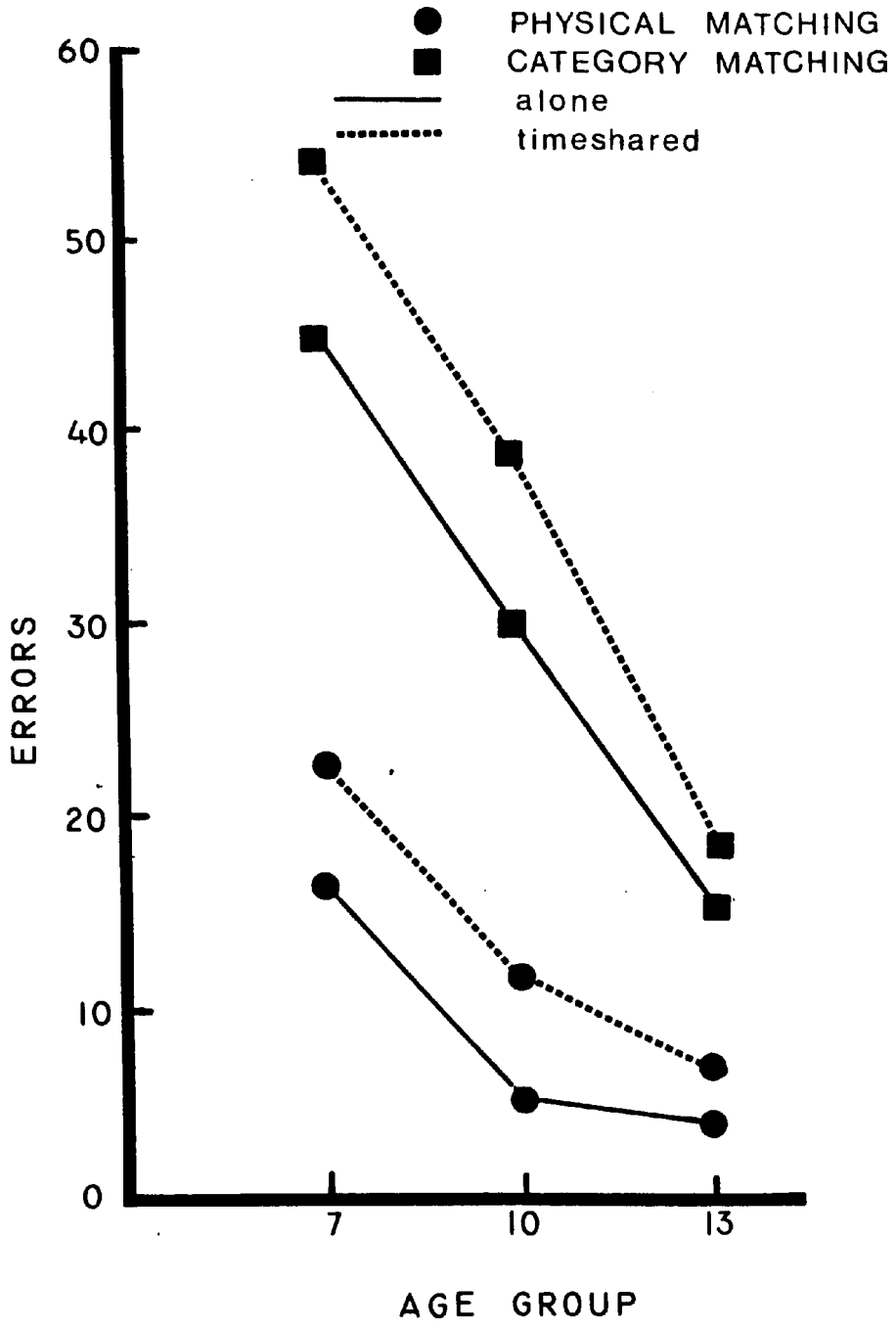


Fig. 6. Auditory matching errors as a function of age group.

To assess the effect of type of match on the performance of the auditory tasks, two 2 x 3 analyses of variance with type of matching task as the repeated measure and age as the second factor were done on the error data. The first analysis used the scores obtained on the matching tasks alone in the A_w and A_c blocks. As can be seen in Figure 6, the effect of type of match was highly significant ($F(1,57) = 291.6$, $p < .001$), with category matching producing more errors for all age groups. The effect of age was also significant ($F(2,57) = 45.1$, $p < .001$), as was the interaction ($F(2,57) = 15.4$, $p < .001$), with the effect of type of match greater for the younger subjects. A corresponding analysis of the error scores for the $Tr+A_w$ and $Tr+A_c$ timeshared blocks showed very similar results. The main effect of type of match was significant ($F(1,57) = 363.5$, $p < .001$); so was the main effect of age ($F(2,57) = 45.4$, $p < .001$) and the interaction ($F(2,57) = 19.1$, $p < .001$). As shown in Figure 6, category matching produced significantly more errors than physical matching for all age groups, and in this sense is the more difficult task. In both performance conditions there was a significant interaction, with the effect of type of match having the greatest impact on the performance of the youngest children.

The omission scores were used in two 2 x 3 analyses of variance for repeated measures with type of matching task as the repeated measure and age as the second factor. In the first analysis the omissions on the A_w and A_c blocks were the dependent measure. The

main effect of type of match was significant, ($F(1,57) = 38.1$, $p < .001$) with category matching producing more omissions. Younger children made significantly more omissions as indicated by the significant main effect of age ($F(2,57) = 23.3$, $p < .001$). The interaction was significant ($F(2,57) = 9.47$, $p < .001$) with type of match producing greater effects on the younger children's performance. Similar results were obtained in the analysis of the omissions of the timeshared blocks, $Tr+A_W$ and $Tr+A_C$. Both main effects and the interaction were significant: type of match ($F(1,57) = 29.8$, $p < .001$); age ($F(2,57) = 25.7$, $p < .001$); Type of Match x Age ($F(2,57) = 6.7$, $p < .01$). These results of the analyses of the omission data are in agreement with those performed on the error scores.

The intratask correlations for the auditory tasks are presented in Table 8. The correlations between both the type of match and performance condition were significant at the $p < .01$ level for the total sample. The correlations between performance conditions for both types of matching tasks were significant at the $p < .05$ level for the 10- and 13-year-olds, while for the 7-year-olds the relationship was significant only for the physical matching task. This suggests that for the youngest children, timesharing tracking with the category matching task produced effects which altered a child's relative position within the group with respect to the performance on category matching.

TABLE 8

AUDITORY TASK INTERCORRELATIONS FOR THE TOTAL SAMPLE AND WITHIN EACH AGE GROUP

Performance Condition	A_W	$Tr+A_W$	A_C	$Tr+A_C$
A_W	---			
$Tr+A_W$	.80**	---		
A_C	.66**	.69**	---	
$Tr+A_C$	.65**	.74**	.81**	---
		7-year-olds		
A_W	---			
$Tr+A_W$	.72**	---		
A_C	.33	.34	---	
$Tr+A_C$	.28	.29	.37	---
		10-year-olds		
A_W	---			
$Tr+A_W$	.58**	---		
A_C	.54*	.34	---	
$Tr+A_C$	.50*	.60**	.71**	---
		13-year-olds		
A_W	---			
$Tr+A_W$	.54*	---		
A_C	.46*	.69**	---	
$Tr+A_C$	.57**	.81**	.64**	---

To investigate how tracking performance might be related to performance on the matching tasks, correlations were obtained for the total sample and for the three age groups. These correlations are presented in Table 9. All of these correlations for the total sample were significantly positive at at least the $p < .01$ level. However, within the age groups the relationships between the tracking and auditory matching tasks are generally non-significant, whether alone or timeshared. Level of performance on the tracking task does not appear to be strongly related to the child's performance on the auditory matching tasks within any age group.

Effect of Instructions on Timesharing

All of the subjects received the same experimental treatment until the completion of Trial 22. At this point they were randomly assigned to one of two instructional groups. Half of the subjects in each age group then were given the tracking primary instruction, the other half the auditory primary instruction. Two two-way analyses of variance with age and instructional group as factors were done using the lnIAE tracking scores for the $Tr+A_c$ block prior to the administration of instructions in the first analysis and the auditory matching errors on the same block in the second. The results of these two analyses indicated that the two instructional groups did not differ significantly in their performance of either task prior to the administration of the instructions.

TABLE 9

CORRELATIONS BETWEEN TRACKING AND AUDITORY MATCHING TASKS FOR THE TOTAL SAMPLE AND WITHIN EACH AGE GROUP

Tracking Task Performance Condition	Auditory Task Condition			
	A_w	$Tr+A_w$	A_c	$Tr+A_c$
Tr_1	.51**	.49**	.60**	.60**
$Tr+A_w$	.53**	.54**	.66**	.66**
Tr_2	.53**	.55**	.64**	.62**
$Tr+A_c$	.48**	.48**	.62**	.61**
	7-year-olds			
Tr_1	.04	-.07	.11	-.12
$Tr+A_w$	.20	.25	.24	.13
Tr_2	.20	.23	.30	.11
$Tr+A_c$	.08	.09	.26	.19
	10-year-olds			
Tr_1	.00	-.34	-.15	-.36
$Tr+A_w$	.00	-.48*	-.03	-.17
Tr_2	.06	-.23	-.11	-.23
$Tr+A_c$	.03	-.44*	.10	-.11
	13-year-olds			
Tr_1	.20	.45*	.21	.47*
$Tr+A_w$	-.01	.47	.27	.34
Tr_2	.01	.41	.34	.34
$Tr+A_c$	-.24	.29	-.05	.05

Tracking Primary Subjects

To determine the impact of the tracking primary instruction on the performance of both tasks in timesharing, a two-way repeated measures analysis of variance with age and instructional condition as factors was done using both the lnIAE scores and the category matching task errors for the tracking primary subjects. The two levels of the instructional factor were the equal emphasis condition of the previous $Tr+A_c$ "both" block and the $Tr+A_c$ "tracking primary" block. The main effects of instruction ($F(1,27) = 31.03$, $p < .001$) and age ($F(2,27) = 23.6$, $p < .001$) were significant for the tracking scores but the interaction was not ($F(2,27) = 1.79$). This failure to obtain significant interaction indicates that although the instructions were effective in producing performance changes in the desired direction, the impact of the instructions on performance was not greater for the older subjects. All three age groups were able to significantly improve their performance on the tracking task when instructed to do so. The corresponding analysis of the non-primary auditory task errors showed a highly significant effect of age ($F(2,27) = 16.09$, $p < .001$), with the youngest subjects showing significantly more errors. Neither the effect of instruction nor the Instruction x Age interaction reached significance. The tracking error scores in lnIAE units and the auditory task errors of the tracking primary subjects appear in Figure 7 for the "both" and "primary" blocks.

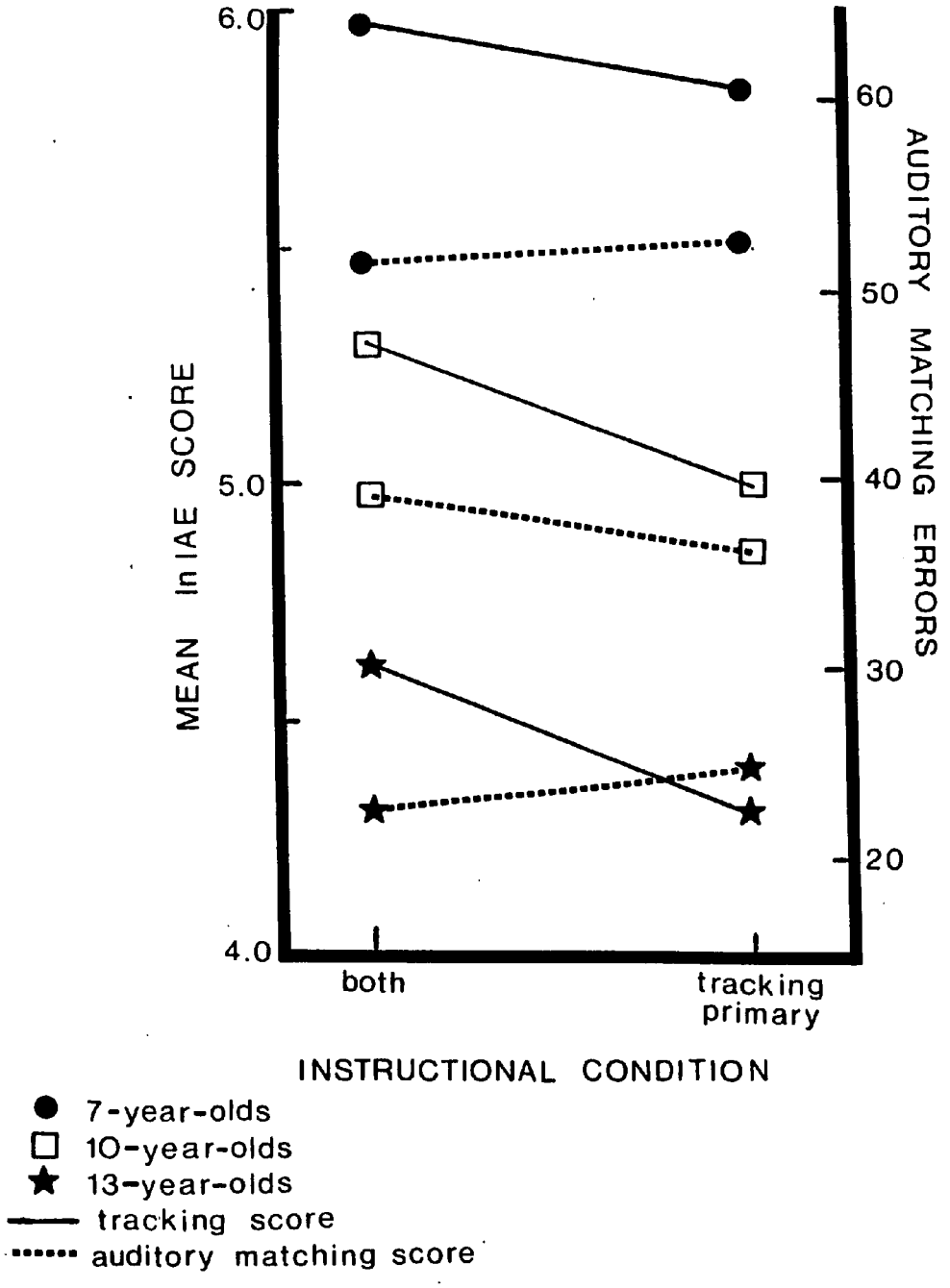


Fig. 7. Mean lnIAE score and auditory matching errors for $Tr+A_C$ blocks with "both" and tracking primary instruction (tracking primary subjects).

Auditory Primary Subjects

The data of the auditory primary subjects were subjected to the same analyses as those of the tracking primary subjects. The results of the two-way repeated measures analysis of variance with age and instructional condition as factors showed both main effects to be significant: Age $F(2,27) = 25.19$, $p < .001$; instruction $F(1,27) = 6.71$, $p < .05$. The interaction was also significant for this group ($F(2,27) = 4.54$, $p < .05$). The auditory task errors and the tracking errors for the "both" and "primary" instructional blocks appear in Figure 8. The interaction has an unexpected form; the impact of the instructions was greatest for the youngest children. The highly significant effect of instruction indicates that the auditory primary subjects were also able to use the instructions to modify their performance in the desired direction, with the instructions producing the greatest change for the youngest group. The results of a corresponding analysis of the non-primary tracking scores indicated that the effect of age was significant ($F(2,27) = 14.2$, $p < .001$), as was the interaction ($F(2,27) = 9.08$, $p < .01$), while the effect of instruction was not. As shown in Figure 8,the youngest group also improved their performance on the non-primary tracking task in the auditory primary block over the previous "both" block, while the tracking scores of the two older groups showed a slight increase in the auditory primary condition.

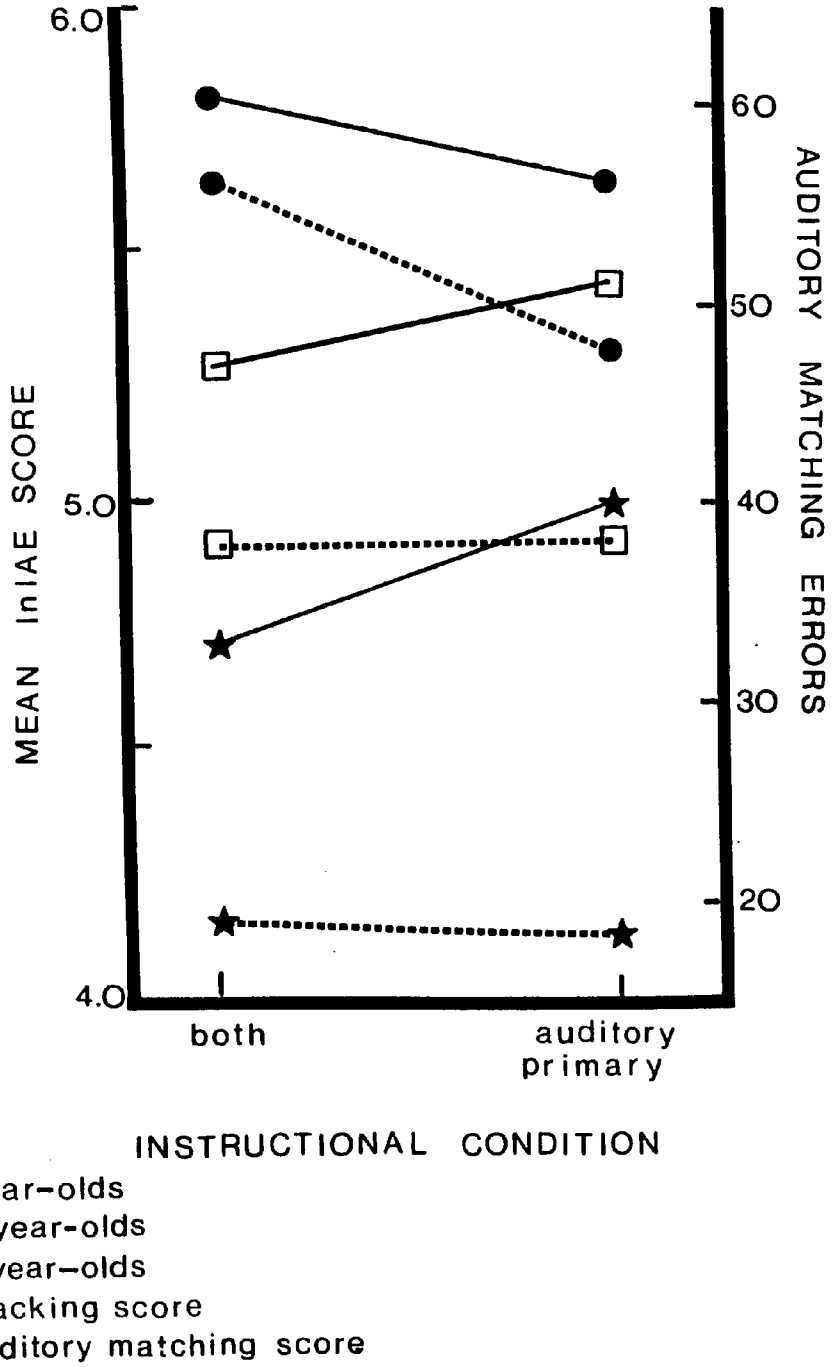


Fig. 8. Auditory matching errors and mean lnIAE score for $Tr+A_c$ blocks with "both" and auditory primary instruction (auditory primary subjects).

Review of Major Findings

1. Timesharing auditory matching with tracking produced significantly greater relative proportional decrements in the tracking performance of the younger than the older subjects. This was true for both physical and category matching.

2. Level of tracking performance was directly related to age, with the youngest subjects showing the largest error scores. However, the rate at which the children improved their performance with practice did not differ significantly with age.

3. Timesharing category matching produced significantly larger proportional decrements in tracking performance relative to those produced by timesharing physical matching for all age groups.

4. Performance on the matching tasks was also directly related to age with the youngest children showing the largest error scores for both types of matching task.

5. Category matching was more difficult than physical matching for all the age groups; category matching produced significantly more errors than physical matching in both performance conditions.

6. In contrast to the effects of matching on tracking performance, timesharing the tracking task did not produce significantly different decrements in either physical or category matching performance as a function of age group.

7. The instructions designed to modify timesharing performance were very effective in producing significant improvement in the performance

of the task emphasized. This was true for all age groups and regardless of whether tracking or matching was the primary task. Instructional condition interacted with age only for the auditory matching primary group where the effect was greatest for the youngest children.

8. At the end of the experimental session the children were asked to try to describe how they were able to do two things at once. No results on this question are reported; almost without exception, the children could not provide answers.

CHAPTER IV

DISCUSSION

It has been demonstrated that category matching produces greater relative decrements in tracking performance than physical matching for all age groups. In addition, all three age groups showed significantly larger error scores on category matching than physical matching in both performance conditions. The direct relationship between primary task difficulty and second task decrements in timesharing previously found in studies with adult subjects appears in the data for each age group. For the children at each age level, making matches on the basis of a rule (i.e., both animals) was more difficult than matching on the basis of physical identity. This is shown both by errors on the matching tasks alone and by relative decrements produced in the subsidiary tracking task during timesharing. The obtained ordering of the matching tasks is the same as that obtained for rule versus physical matching using visually presented letters as stimuli. Posner and Mitchell's (1967) adult subjects produced longer reaction times for rule matching and these longer reaction times were used as evidence for rule matching requiring relatively more information processing than physical matching.

As expected, timesharing the matching tasks was shown to have a decreasing impact on tracking performance with increasing age. In addition, older children made significantly fewer errors than younger children on the matching tasks when performed alone. This was true

for both physical and category matching. The general relationship between primary task difficulty and secondary task decrements that has been noted with respect to type of matching task in the present study, and in other timesharing studies using the secondary task technique, appears when the age groups are compared: decreasing error scores with age on the matching tasks are accompanied by a corresponding decrease in proportional tracking decrements.

While timesharing the matching tasks has been shown to have an impact on tracking performance that decreases with increasing age, no such effect is found when the effects of tracking on matching are examined. The decrements produced in both category and physical matching by timesharing do not differ with age. The secondary task method is based on the assumption that any differing demands made by the first task are reflected solely in performance changes in the subsidiary task. In this instance, if performance decrements on the matching tasks had also interacted with age, unambiguous interpretation of the tracking data within the secondary task method would not be possible. Taking a more general view of the data and focusing on the question of developmental trends in timesharing performance, the asymmetry in the data suggests that any general statements about age differences in timesharing even for one particular primary task must await the collection of data using other tasks in combination, including pairing a task with several secondary tasks. This is necessary in order to exclude the possibility that the results of the

present study are specific to the particular tasks and combinations used,and to ascertain whether it is useful to assume the existence of some general ability to timeshare that is independent of the effects of timesharing which can be attributed to particular task and modality combinations.

An examination of the results of the matched subjects data underscores the need for further research. The results from the total sample have shown that the errors on a secondary task are directly related to the relative difficulty of the matching task. This relationship is not apparent in the matched group data, where subjects were matched on the basis of their tracking scores. In the younger-older comparison there were no significant differences in the level of tracking performance subsequent to the criterion block in timesharing either type of matching task or in the size of the decrements obtained in timesharing. However, the subjects who were matched on tracking performance showed different error scores on both types of matching tasks performed alone and timeshared, with younger subjects showing significantly higher error scores. Unlike the total sample, for these matched subgroups the level of tracking performance in the baseline condition seems to provide a better indication than matching task performance of the relative decrements obtained in timesharing the tracking task. It was not possible to match subjects from different age groups on the basis of their matching performance in sufficient numbers to obtain additional information on the relationship

between matching task difficulty and tracking task decrements. In the present study the level of performance on both matching and tracking tasks is confounded with age group. Giving younger children sufficient practice on both tasks alone in order to make their performance on the tasks indistinguishable from older children's and then comparing their timesharing performance would provide the necessary information to begin to separate the effects of learning and practice from differences attributable to level of development.

Contemporary attentional models differ on the question of the nature and locus of interference effects in the performance of concurrent activities. Generally, if greater relative decrements are obtained in a subsidiary task for one task than another, then these results are interpreted as reflecting greater relative demands for limited processing capacity. Whether the secondary task decrements are attributed to a "general capacity overload" where the capacity demanded exceeds that which can be supplied by the individual (Kahneman, 1973), or to competing operations that simultaneously require a central limited capacity mechanism (Keele, 1973), category matching is seen within both views as making relatively greater demands for central processing capacity than physical matching for the children of each age group.

The results of the present study suggest the existence of processing differences which are responsible for the age differences in timesharing, but they do not provide information about the specific

nature of the processing differences. There are at least three possibilities:

1. The first corresponds to an interpretation using Kahneman's concepts: older and younger children are using the same strategies to perform the tasks and performance differences are attributable to differences in the skill with which the appropriate strategy is applied. Under the assumptions of the model, these skill differences result in differences in the capacity supplied to the task.

2. Older and younger children are using qualitatively different processes and strategies to perform the tasks. The performance differences in timesharing are due to the different patterns of interference produced when different process combinations simultaneously require the use of the central limited capacity mechanism. This alternative is suggested by Keele's (1973) formulation, where some but not all processes require attention and decrements in timesharing occur when the mental operations simultaneously require the mechanism.

3. A third possibility corresponds to Moray's (1967) suggestion that the organization and coordination of joint performance itself demands attention. Performance differences in timesharing obtained as a function of age could be attributed to these differing organizational demands.

These three alternatives may be differentially appropriate in describing the results of different task combinations. It should be possible to distinguish experimentally between the first two

hypotheses for a given task by pairing a task with several different secondary tasks which are all equally difficult within each age group when performed alone. Differences with age in the patterns of interference produced in timesharing could then be noted. The first alternative predicts that timesharing the secondary tasks should produce equivalent decrements within an age group since all the secondary tasks are equally demanding. The second alternative predicts that only tasks which simultaneously demand the central mechanism should interfere. If the age groups show different patterns of the subsets of secondary tasks which produce task interference in timesharing, this would suggest that the groups were using different processes to perform.

An examination of the microstructure of timesharing by analysis of analog data that provided measures of frequency and duration could provide information on the third possibility. Younger children may have a more difficult time in coordinating two activities in timesharing. This third alternative could operate in addition to either of the first two possibilities to produce performance differences in timesharing.

Kahneman (1973) does not specify the form of the relationship between capacity supplied and quality of performance. This makes it impossible to give an unambiguous interpretation of the developmental differences in patterns of timesharing decrements within the model. The concept of capacity cannot account for all changes in quality of performance produced in timesharing. For example, studies have shown

that with practice on a primary task, performance decrements on a second concurrent activity decrease (Bahrick & Shelly, 1958; Bahrick, Noble & Fitts, 1954); changes in the level of skill with respect to the primary task also produce performance changes in the second task. Kahneman (1973) interprets this finding as reflecting decreased demands for capacity with practice. Apparently, his implicit assumption is that performance is some monotonic function of skill and capacity and that there is a compensatory relationship between the two factors which combine to produce performance. As long as both capacity allocated and skill exceed some lower limit, equivalent performance can be produced by various combinations of skill and capacity:

$$\text{Performance} = f(\text{Capacity}, \text{Skill})$$

and changes in performance may be attributable to skill changes, capacity changes or both.

The general notion that older children have more practice on task-appropriate skills as well as the significantly better performance of the older children on the matching tasks in the baseline conditions suggests that the older children are relatively more skilled than the younger children. It is assumed that a compensatory relationship exist between capacity and performance and that older children have greater skills to apply to the matching tasks. In combination with the finding that the older children show smaller proportional decrements in the tracking task in timesharing than the younger children, this implies that the matching tasks were relatively

more demanding for the younger children. These younger children then had relatively less capacity to devote to the tracking task. In other words, the same task demands relatively more of the total capacity of a younger, less skillful subject. The older child has relatively greater spare capacity to allocate to other processes or activities.

Such an interpretation, however provocative, is dependent upon the precise form of the function relating capacity and performance. When the relationship is a linear one and changes in the skill parameter simply produce slope changes, the conclusion is valid. Here a change in quality of performance at different levels of performance implies equal changes in capacity supplied for a given level of skill. If the relationship is nonlinear such a conclusion is not necessarily valid. One possible alternative to the assumption of linearity is that quality of performance is a negatively accelerated function of capacity supplied. Here, the same change in quality of performance at different levels of performance can imply unequal changes in the capacity supplied for a given level of skill. If the relationship is nonlinear such a conclusion is not necessarily valid. One possible alternative to the assumption of linearity is that quality of performance is a negatively accelerated function of capacity supplied. Here, the same change in quality of performance at different levels of performance can imply unequal changes in the capacity supplied for a given level of skill. In this case no such conclusions about developmental differences in capacity supplied can

be drawn on the basis of differing performance decrements. Although this criticism of Kahneman's (1973) model (which applies to Keele's (1973) formulation as well) has arisen in the context of interpreting age differences in timesharing performance, the criticism is not specific to this context. Rather, it points to a deficiency in current models of attention which makes the interpretation of obtained performance differences in terms of differing demands for attention or capacity questionable.

All age groups in both instructional conditions were able to modify their timesharing performance in the instructed directions. Verbal instructions about task priorities proved to be a powerful factor in determining the locus of decrements in timesharing. The expectation that older children should be more able to use verbal instructions was not supported and in fact, for the group instructed that the matching task was primary, the effect was greatest for the youngest children. These seven-year-olds, who improved their matching task performance in the primary block over the preceding equal emphasis block also improved their non-primary tracking performance. Unlike Murdock's (1965) adult subjects, the seven-year-olds did not trade off larger decrements in the non-primary task for improved performance on the other; only the thirteen-year-olds in this instructional group appeared to be trading off one task for the other in the manner of Murdock's (1965) adults.

Since subjects possess some set of priorities about the relative importance of the timeshared tasks even in the absence of explicit

instructions, probably based on environmental cues or expectancies, the results stress the methodological importance of unambiguously conveying the task priorities to the subject so that obtained effects can be attributed with greater confidence to other factors being investigated.

It is significant that even the youngest children were able to timeshare two complex tasks, each requiring considerable skill, with some success. Generally, the better performance of the older children on the tasks alone has been reflected in their superior timesharing performance. The method thus provides another index of performance. In addition, the results of the present study suggest that timesharing can provide important information about age differences in the performance of an activity not revealed by the usual measures of performance: differences with age in the degree to which a task is compatible with a second activity. In their everyday experience children often do two things at once, and the study of the phenomenon per se needs to be pursued. In addition, although timesharing is a method that has many methodological pitfalls, its careful application can yield new information about the nature and locus of developmental differences in cognitive processes.

APPENDIX I

STIMULUS LISTS USED IN AUDITORY MATCHING TASKS

Physical Matching (A_W)

Stimulus Lists 1-6

LIST 1

milk dress
nose bird
frog frog
stew stew
glove glove
dog cheek
cap cap
bread foot
shoe coat
peach peach
leg chin
fox bug
cake cake
mouth mouth
belt soup
pie pie
goat swan
boot cream
face face
jam wrist
duck duck
brain skin
tie tie
bread pie
grape grape
head head
pig pig
cream scarf
chest neck
beef beef

LIST 2

arm arm
suit cream
fudge fudge
toe skirt
nut nut
egg egg
scarf scarf
fish steak
mouse mouse
thigh sheep
milk milk
stew face
frog cake
dog dog
peach chin
bread bread
tie foot
leg leg
bread fox
dress nose
duck scarf
belt belt
cheek cheek
grape cat
boot boot
pie wrist
brain brain
cream dress
meat meat
glove glove

LIST 3

sheep bug
chest chest
nut nut
glove coat
bird bird
skin skin
pig egg
cap face
jam fish
thigh thigh
cheek cheek
suit suit
beef pig
goat goat
tie soup
milk swan
stew stew
wrist frog
fox pie
foot foot
bread cat
mouth deer
nose nose
milk shoe
belt belt
dog dog
neck peach
fish fish
scarf scarf
arm leg

LIST 4

fox fox
tie arm
stew peach
leg leg
duck goat
shoe goat
shoe neck
cake cake
toe toe
fish fish
cap bread
nut grape
thigh cat
deer deer
dress egg
fudge fudge
head head
swan cat
coat coat
nut nut
cheek foot
goat goat
belt belt
milk steak
neck neck
frog nose
glove stew
pie pie
brain mouse
dog dog
coat bird

LIST 5

beef egg
face face
mouse mouse
dress fox
jam jam
stew stew
cat pie
scarf foot
grape peach
leg leg
duck duck
shirt skirt
milk soup
brain brain
fish swan
coat glove
peach peach
foot neck
goat dog
dress dress
pie grape
toe face
mouse mouse
cap deer
bread bread
foot foot
pig bird
glove glove
soup mouth
cream cream

LIST 6

scarf scarf
skin chest
pie deer
cat cat
tie leg
cheek dog
peach peach
fish fish
cap cap
nose belt
milk nut
fox neck
skirt skirt
mouth grape
egg egg
frog frog
glove leg
foot foot
jam jam
swan deer
dress dress
chin chin
grape grape
pig pig
shoe arm
cheek suit
cake cake
bug pie
belt belt
mouth chin

Category Matching (A_c)

Stimulus Lists 1-9

LIST 1

stew cake
pig fish
peach coat
duck nose
beef shoe
sheep deer
bread wrist
egg pie
cheek toe
foot belt
leg arm
skirt glove
frog neck
jam chest
face skin
bird scarf
dog swan
milk nut
thigh boot
fudge steak
suit cap
goat bug
brain dress
nose head
meat tie
grape chin
pig cream
cat fox
stew belt
tie fish

LIST 2

leg duck
peach egg
dress bird
nose chest
grape wrist
skirt pie
sheep toe
cat pig
stew glove
face cheek
meat cap
bug swan
cake milk
dress frog
cream steak
skin boot
head neck
coat dog
fox goat
shoe scarf
nut beef
arm deer
mouse tie
brain foot
coat egg
bird fish
thigh chest
beef egg
mouth cat
chin bug

LIST 3

belt cap
cake fox
foot head
stew nut
skirt brain
deer toe
belt shoe
cream grape
pig dog
fudge wrist
neck frog
scarf leg
milk pie
meat glove
sheep swan
bread peach
dress leg
face nose
duck goat
boot chest
skin arm
grape fudge
steak cheek
deer cat
jam bug
fish shoe
foot thigh
cap egg
chin peach
cat bird

LIST 4

pig bird
chest stew
milk cat
scarf dress
duck frog
brain peach
beef jam
cap leg
deer sheep
nose cheek
pie toe
scarf goat
sheep tie
foot neck
egg cream
belt meat
swan fox
head chest
fudge cake
shoe leg
fish bug
deer bread
boot milk
coat glove
fox beef
wrist face
thigh grape
skirt suit
cat pig
brain swan

LIST 5

shoe coat
swan foot
neck chin
bread fudge
tie grape
goat pie
thigh toe
beef cap
scarf belt
sheep duck
face arm
pie foot
skirt milk
fish bird
cheek jam
egg fox
dress glove
frog dog
wrist bread
fudge deer
coat belt
pig sheep
head pie
peach nut
cap mouth
bug bird
skin grape
foot cake
glove dress
fish arm

LIST 6

brain swan
cat pig
dress skirt
thigh egg
face wrist
beef fox
glove coat
milk dog
bread face
bug fish
leg shoe
cake fudge
chest head
fox swan
meat belt
cream egg
neck foot
tie bird
goat scarf
toe pie
cheek nose
sheep deer
arm cap
jam steak
peach brain
frog duck
dress belt
cat milk
chest stew
bird pig

LIST 7

arm fish
dress glove
cake foot
grape skin
bird pig
bird bug
neck cap
nut peach
pie head
sheep pig
belt coat
deer fudge
bread wrist
dog swan
glove dress
fox egg
jam cheek
bird fish
milk skirt
foot peach
arm face
duck sheep
belt scarf
cap beef
toe thigh
pie goat
grape tie
fudge bread
chin neck
foot swan
coat shoe

LIST 8

fish tie
belt stew
fox cat
cream dog
chin grape
tie meat
head foot
dress brain
bug goat
cap dress
steak fudge
boot thigh
nut milk
swan dog
scarf bird
skin face
chest jam
neck frog
glove skirt
arm leg
belt foot
toe cheek
pie egg
wrist bread
deer sheep
shoe beef
nose duck
coat peach
fish pig
cake stew

LIST 9

bug chin
cat nose
egg beef
chest thigh
fish bird
pie coat
foot brain
tie mouse
deer arm
beef nut
scarf shoe
goat fox
dog coat
neck head
boot skin
steak cream
frog dress
milk cake
swan bug
cap meat
cheek face
glove stew
pig cat
toe sheep
pie skirt
wrist grape
chest nose
bird dress
egg peach
duck leg

APPENDIX II

INSTRUCTIONS FOR THE EXPERIMENTAL SESSION

Instructions

The instructions were presented in a fairly standardized form. Particular care was taken that the instructions in the last portion of the study were presented with equivalent phrasing and emphasis to all subjects within both instructional conditions.

The first game I have for you to play is called a tracking game. See these two dots? This one is your dot and the other one is the target dot. Your dot moves the way you want it to when you turn this knob. See? You try it. Your job is going to be to pay attention to your dot and try as hard as you can to keep it on top of the target dot as much of the time as you can. It looks simple now but it will be pretty hard to do when I turn the machine on because your dot will start moving around all by itself. First you'll practice playing the tracking game ten times. Each time only lasts one minute and I'll tell you when to start. Every time you play the tracking game you'll get a score. The lower the number you get for a score the better you're doing. For example, if you got a score of zero that would mean that you had done a perfect job and had kept your dot on top of the target the whole time the machine was turned on; that's too hard to do and no one ever does that well. What I'd like you to do is to try hard to do better each time you play than you did the time before. Are you ready to try it? Do you have any questions? O. K. Try as hard as you can to keep your dot on top of the target dot. Ready? Go. (During trial one a few of the youngest subjects

were shown which direction to turn the knob in order to move the dot towards the target).

10 Tracking Trials

Now I have another game for you to try. In a minute I'm going to have you put on this headset and listen to some pairs of words. If the two words in the pair you hear are the same word I want you to say "yes". If the two words you hear are different words say "no". So if you hear "cake, cake" say "yes", and if you hear something like "cake, pie", say "no". Let's try a few before we start. (Several examples were given until it was apparent that the child understood his task). There are thirty pairs in a group and each group only lasts one minute so they'll be pretty fast. You'll hear three groups with little rests between them. Questions? Ready? Remember, say "yes" if the two words are the same word and "no" if they are different words.

Three Physical Matching (A_w) Trials

This time I want you to try playing both of the games at the same time. Pay attention to both games and try hard to do as well as you can on both of the games. You'll hear three groups of words and will play the tracking game three times. We'll start both games when you start hearing the words. Questions? Remember, pay attention to both games and do both just as well as you can. Ready?

Three ($Tr+A_w$) Timeshared Trials

Now play the tracking game three times all by itself. Do it as well as you can.

Three Tracking Trials

Rest
(2 min.)

This time you'll hear more pairs of words but this time the rules for saying yes and no are different. You will hear four kinds of words: animals, clothing, parts of the body and food. This time say "yes" if the two words in the pair are the same kind of word and say "no" if they're different kinds of words. So if both the words are names of things to eat, like "cake, pie", say "yes", or if they are both names of animals, like "dog, cat", say "yes", or if both are parts of the body, like "head, foot", say "yes", or if both are names of things to wear, like "shoe, coat", say "yes". But if the words are different kinds of words like "cake, dog", or "arm, shoe" I want you to say "no". O.K.? Let's try a few (examples given until it is apparent that the child understands the rules). Just like before the words are in three big groups with little rests in between. They will be just as fast as the other ones so pay attention and just do the best job you can. Questions? Remember, say "yes" if they are the same kind of word and "no" if they are different kinds of words. Ready?

Three Category Matching (A_c) Trials

Next I want you to play both games at the same time. Pay attention to both games and try to do both games just as well as you can.

You'll play both games three times just like before. Questions? Ready?

Three ($Tr+A_c$) Timeshared Trials

Now play the tracking game three times all by itself. Do it as well as you can.

Three Tracking Alone Trials

Rest
(2 min.)

This time I want you to try doing two things at the same time again. You'll be playing the word game where you say "yes" if the two words in the pair are the same kind of word and "no" if they are different kinds of words (examples if necessary) and the tracking game three times. This time though I want you to think about what you're doing differently. Think about the tracking (word) game as being the most important thing you have to do. I want you to pay more attention to the tracking (word) game and try hard to do better on the tracking (word) game than you did the last time you did both things at the same time. Questions? Ready?

Three ($Tr+A_c$) Timeshared Trials

Now try the tracking game three last times before we finish.

Three Tracking Alone Trials

(interview) Before you go can you tell me something about what you did so that you were able to do two things at the same time? Did it feel like you were really playing both games at the same time? Did you do one first and then the other?

APPENDIX III

RAW DATA FOR INDIVIDUAL SUBJECTS: INTEGRATED ABSOLUTE ERROR (IAE) SCORES TRACKING TRIALS 1-28, AND AUDITORY MATCHING TASK ERRORS TRIALS 1-15

Seven-year-olds

Auditory Primary Instruction

Tracking Trial Number	Auditory Task Trial Number	Subject Number 1		2		3		4		5	
1		160		152		120		78		120	
2		160		100		74		71		112	
3		100		112		54		55		98	
4		120		70		54		40		75	
5		60		76		56		40		72	
6		70		100		56		42		72	
7		55		80		57		39		52	
8		52		56		47		35		58	
9		66		65		45		41		55	
10		60		80		49		31		55	
	1		3		2		3		7		6
	2		8		3		2		6		14
	3		5		2		9		2		5
11	4	82	6	95	7	60	8	78	12	80	7
12	5	240	7	120	9	55	10	98	8	68	6
13	6	200	13	96	5	48	9	50	6	65	7
	7	80		60		45		28		50	
	8	80		64		41		22		55	
	9	68		58		45		24		75	
14	10		12		10		19		5		9
15	11		17		10		19		12		12
16	12		14		8		18		10		18
17		128	17	168	29	98	19	60	17	65	21
18		160	20	128	23	90	18	66	13	140	26
19		140	17	112	27	112	19	104	16	68	15
20		84		66		30		35		52	
21		88		47		30		34		70	
22		80		50		32		32		60	
23	13	280	13	196	23	62	18	42	11	62	17
24	14	200	14	88	18	65	17	70	14	77	13
25	15	128	16	108	21	104	18	72	12	128	12
26		63		55		30		36		70	
27		85		46		29		40		55	
28		90		40		28		26		65	

Seven-year-olds

Auditory Primary Instruction

Tracking Trial Number	Auditory Task Trial Number	Subject Number 6		7		8		9		10	
1		100		76		94		88		98	
2		95		68		90		58		83	
3		90		38		100		65		100	
4		100		46		89		90		76	
5		70		50		88		70		88	
6		72		36		80		78		85	
7		58		34		85		68		80	
8		94		34		60		66		83	
9		85		31		55		85		100	
10		75		33		70		64		70	
	1		5		4		9		3		8
	2		1		6		7		6		16
	3		9		5		6		1		9
11	4	108	10	40	5	120	13	85	2	116	11
12	5	94	4	50	6	116	12	91	4	120	11
13	6	104	8	59	6	96	17	152	4	98	11
	7	66		23		57		50		80	
	8	70		21		56		46		68	
	9	57		24		80		46		64	
14	10		13		10		19		21		11
15	11		11		17		20		15		13
16	12		17		10		16		16		14
17		120	18	65	16	140	19	136	20	132	22
18		104	16	86	12	148	19	168	15	160	25
19		120	17	72	16	112	17	108	14	172	19
20		58		20		89		80		61	
21		65		19		65		54		84	
22		52		25		70		47		72	
23	13	98	16	65	15	90	23	85	12	98	23
24	14	120	9	55	14	112	16	60	15	116	20
25	15	128	15	47	15	76	12	85	16	83	21
26		55		17		65		54		77	
27		95		19		82		100		51	
28		85		18		65		65		56	

Seven-year-olds

Tracking Primary Instruction

Tracking Trial Number	Auditory Task Trial Number	Subject Number 11		12		13		14		15	
1		116		128		160		112		88	
2		88		48		152		52		78	
3		98		60		140		65		72	
4		116		38		116		85		65	
5		95		64		140		82		59	
6		64		80		180		62		84	
7		100		56		128		50		54	
8		90		70		168		55		58	
9		85		48		116		65		52	
10		68		54		120		62		70	
	1		8		6		0		0		6
	2		12		1		4		0		5
	3		16		0		3		6		10
11	4	168	12	112	5	120	3	60	3	92	7
12	5	140	11	160	4	140	3	92	5	108	11
13	6	216	18	76	1	140	3	75	5	94	8
	7	88		33		88		40		74	
	8	100		36		100		52		53	
	9	72		66		100		50		73	
14	10		17		22		13		9		27
15	11		20		13		15		10		26
16	12		20		14		13		12		26
17		160	16	248	24	164	9	120	14	112	29
18		272	17	120	20	228	14	120	11	160	27
19		208	20	164	22	160	13	112	10	152	25
20		88		41		108		62		68	
21		96		56		140		72		78	
22		62		44		96		62		80	
23	13	216	19	152	20	104	15	112	19	128	29
24	14	216	17	160	20	120	16	120	17	136	26
25	15	260	18	152	22	120	15	152	22	120	30
26		128		45		72		53		70	
27		288		55		76		62		70	
28		124		50		88		59		85	

Seven-year-olds

Tracking Primary Instruction

Tracking Trial Number	Auditory Task Trial Number	Subject Number 16		17		18		19		20	
1		83		98		120		124		94	
2		68		85		75		120		93	
3		74		68		58		85		64	
4		65		72		57		80		54	
5		65		46		55		85		100	
6		50		55		42		94		67	
7		59		53		48		112		63	
8		60		47		50		104		65	
9		72		50		48		104		65	
10		65		45		52		92		61	
	1		4		0		8		2		8
	2		2		1		9		5		5
	3		1		9		8		8		6
11	4	58	3	95	5	65	8	120	6	85	12
12	5	80	7	112	15	96	9	148	9	88	6
13	6	98	6	85	6	70	2	120	6	80	8
	7	64		45		33		96		64	
	8	52		68		55		92		55	
	9	58		58		37		87		55	
14	10		8		16		15		16		19
15	11		9		17		10		14		18
16	12		10		16		15		18		21
17		116	12	116	16	75	17	160	17	50	16
18		95	15	124	18	85	22	176	14	65	18
19		85	13	99	24	120	18	176	15	85	14
20		60		46		37		96		42	
21		60		58		31		78		45	
22		70		55		43		98		44	
23	13	120	11	66	20	60	15	120	14	55	16
24	14	90	10	108	14	83	17	160	16	66	19
25	15	78	7	120	20	104	17	132	15	39	13
26		58		55		33		95		34	
27		64		54		39		85		62	
28		50		30		37		95		39	

Ten-year olds

Auditory Primary Instruction

Tracking Trial Number	Auditory Task Trial Number	Subject Number 26		27		28		29		30	
1		95		85		56		100		77	
2		46		57		51		51		41	
3		41		46		45		54		28	
4		41		38		50		52		26	
5		44		42		50		44		37	
6		39		51		40		39		41	
7		45		39		42		44		27	
8		31		36		44		55		28	
9		35		33		45		41		27	
10		23		39		42		56		30	
	1		1		1		0		2		0
	2		3		5		1		0		2
	3		1		3		2		2		1
11	4	80	5	26	6	64	1	40	3	61	3
12	5	61	8	34	7	68	2	46	5	58	2
13	6	55	5	40	7	54	2	40	3	53	3
	7	32		38		45		28		19	
	8	39		36		32		24		20	
	9	37		42		32		32		16	
14	10		11		9		6		9		12
15	11		18		17		10		4		10
16	12		9		10		4		8		14
17		49	18	60	18	55	4	54	12	55	16
18		95	17	35	17	61	1	55	9	50	14
19		48	18	41	12	59	4	45	13	40	16
20		33		40		33		50		17	
21		33		33		44		32		19	
22		34		47		48		34		18	
23	13	45	19	85	19	72	8	55	12	38	17
24	14	44	19	50	15	81	6	96	8	53	16
25	15	69	19	58	14	62	11	90	7	42	17
26		31		26		60		26		17	
27		36		25		41		24		16	
28		36		45		36		28		15	

Ten-year-olds

Auditory Primary Instruction

Tracking Trial Number	Auditory Task Trial Number	Subject Number 21		22		23		24		25	
1		65		128		55		63		120	
2		120		96		76		59		74	
3		72		80		80		55		72	
4		58		63		100		54		90	
5		58		57		42		63		72	
6		62		46		45		55		52	
7		54		52		35		53		60	
8		74		52		48		51		60	
9		42		48		29		50		70	
10		38		45		28		44		60	
	1		4		0		5		2		0
	2		1		2		1		2		0
	3		3		1		7		0		0
11	4	52	2	128	2	62	5	74	5	75	2
12	5	72	1	57	4	72	6	72	5	72	1
13	6	87	5	51	0	51	10	58	1	73	2
	7	38		52		39		44		48	
	8	29		49		37		44		48	
	9	37		57		46		41		52	
14	10		12		14		13		12		6
15	11		9		11		12		13		0
16	12		16		15		12		10		0
17		54	12	128	12	78	16	78	10	58	8
18		68	14	128	13	68	12	62	14	112	12
19		78	14	98	14	78	17	68	16	60	5
20		40		62		29		58		50	
21		32		34		27		43		50	
22		52		40		46		44		60	
23	13	100	12	104	16	78	18	80	11	100	2
24	14	112	11	84	16	120	18	84	9	75	3
25	15	104	11	96	14	72	16	100	12	75	4
26		31		34		25		32		80	
27		38		45		29		45		75	
28		34		31		36		46		70	

Ten-year-olds

Tracking Primary Instruction

Tracking Trial Number	Auditory Task Trial Number	Subject Number 31		32		33		34		35	
1		75		58		100		51		56	
2		53		36		80		37		46	
3		60		29		67		34		44	
4		65		26		55		53		52	
5		49		30		60		28		60	
6		53		29		51		31		41	
7		42		35		60		34		39	
8		55		30		48		37		44	
9		32		32		65		24		50	
10		30		31		40		26		41	
	1		0		0		0		0		1
	2		0		3		1		3		0
	3		0		1		4		2		3
11	4	56	0	28	2	88	3	31	3	44	7
12	5	50	0	20	5	100	2	37	7	26	6
13	6	56	1	28	4	116	2	32	8	31	11
	7	29		24		37		21		27	
	8	29		24		90		21		27	
	9	35		20		45		24		38	
14	10		12		7		7		5		11
15	11		10		5		2		7		11
16	12		12		11		5		11		11
17		66	10	26	8	120	9	20	12	30	13
18		80	10	24	9	78	11	26	18	42	15
19		74	18	26	17	85	7	23	17	31	11
20		39		19		24		20		22	
21		100		26		34		19		24	
22		38		22		24		22		25	
23	13	50	12	20	15	48	9	20	17	25	17
24	14	100	3	18	11	45	7	25	13	27	12
25	15	42	9	23	11	44	5	19	13	25	8
26		30		19		22		17		34	
27		36		18		34		18		24	
28		31		18		27		16		23	

Ten-year-olds

Tracking Primary Instruction

Tracking Trial Number	Auditory Task Trial Number	Subject Number 36		37		38		39		40	
1		100		78		63		56		52	
2		88		52		55		50		44	
3		120		47		84		63		60	
4		80		48		42		38		39	
5		77		55		48		40		39	
6		63		40		44		39		47	
7		58		50		62		50		38	
8		54		48		48		55		54	
9		45		45		58		41		100	
10		50		48		62		43		40	
	1		0		0		5		2		3
	2		7		2		1		1		5
	3		0		4		0		1		4
11	4	75	3	66	6	91	0	60	2	52	9
12	5	88	6	128	8	81	1	62	3	52	5
13	6	90	4	65	1	88	0	108	3	64	3
	7	58		40		48		42		31	
	8	60		48		58		59		28	
	9	50		44		42		47		29	
14	10		11		12		5		9		16
15	11		12		8		16		10		18
16	12		10		11		9		11		16
17		168	13	112	16	128	9	66	9	58	14
18		120	17	100	16	156	14	128	12	61	16
19		112	16	160	12	100	9	136	14	51	22
20		40		45		50		54		45	
21		54		34		47		61		33	
22		52		44		52		40		30	
23	13	100	14	40	14	95	11	51	11	65	11
24	14	108	14	68	22	92	12	48	8	47	16
25	15	160	12	46	15	148	11	72	10	58	18
26		41		50		70		42		45	
27		47		45		68		50		38	
28		52		50		60		108		39	

Thirteen-year-olds

Auditory Primary Instructions

Tracking Trial Number	Auditory Task Trial Number	Subject Number 41		42		43		44		45	
1		40		58		48		82		48	
2		36		26		32		43		26	
3		26		49		32		45		20	
4		25		28		29		39		19	
5		23		25		28		52		20	
6		28		32		28		44		22	
7		22		32		26		31		18	
8		23		40		29		35		20	
9		32		36		28		32		26	
10		21		25		26		40		20	
	1		0		4		2		0		0
	2		4		3		0		0		2
	3		2		8		1		0		0
11	4	28	4	30	3	20	0	56	3	14	0
12	5	32	2	20	2	26	1	46	0	28	2
13	6	45	3	25	0	24	0	46	0	30	3
	7	21		18		24		20		14	
	8	23		17		25		20		20	
	9	22		20		24		22		22	
14	10		6		4		4		6		7
15	11		4		2		10		4		5
16	12		2		7		5		2		5
17		35	8	22	8	21	2	46	5	34	6
18		33	7	23	9	29	2	56	7	50	4
19		44	8	26	13	24	3	56	7	50	4
20		22		24		19		18		13	
21		23		21		24		20		11	
22		23		21		25		21		20	
23	13	39	7	47	11	24	1	88	9	42	1
24	14	44	8	40	11	36	2	64	3	62	5
25	15	52	6	35	9	30	1	56	5	71	4
26		18		15		18		19		13	
27		15		16		17		19		15	
28		21		16		22		24		17	

Thirteen-year-olds

Auditory Primary Instruction

Tracking Trial Number	Auditory Task Trial Number	Subject Number 46		47		48		49		50	
1		68		60		100		77		36	
2		33		33		50		42		26	
3		33		42		40		55		25	
4		40		37		38		42		25	
5		34		36		33		29		23	
6		37		36		38		33		27	
7		47		52		38		32		20	
8		33		33		42		54		14	
9		32		30		29		45		15	
10		33		22		28		37		13	
	1		0		0		2		3		0
	2		0		0		1		5		1
	3		0		0		0		1		0
11	4	37	0	38	0	26	1	45	3	13	0
12	5	38	1	45	2	40	3	55	15	16	0
13	6	39	5	37	0	24	0	55	8	12	1
	7	28		26		24		27		11	
	8	30		26		27		32		14	
	9	29		25		27		35		9	
14	10		2		3		4		6		3
15	11		3		3		6		11		4
16	12		1		5		2		5		5
17		75	4	41	4	40	2	75	9	16	3
18		75	13	55	1	43	6	72	15	14	2
19		60	8	46	0	34	7	73	10	17	2
20		34		40		16		35		12	
21		34		34		22		34		11	
22		31		32		18		32		12	
23	13	120	4	53	1	26	4	104	13	20	1
24	14	120	13	40	2	38	6	64	5	15	2
25	15	104	10	58	2	49	4	90	13	17	2
26		33		32		18		42		10	
27		28		32		23		28		9	
28		31		29		22		32		9	

Thirteen-year-olds

Tracking Primary Instruction

Tracking Trial Number	Auditory Task Trial Number	Subject Number 51		52		53		54		55	
1		54		36		80		25		62	
2		32		36		44		31		28	
3		35		30		54		29		31	
4		30		40		44		28		55	
5		26		60		37		32		25	
6		24		39		42		32		29	
7		29		37		50		50		25	
8		23		27		55		25		22	
9		25		30		48		34		21	
10		23		35		48		30		24	
	1		2		0		1		0		0
	2		4		1		0		2		0
	3		4		0		1		6		0
11	4	30	0	27	0	60	4	20	0	40	0
12	5	50	7	29	1	62	2	26	1	49	0
13	6	36	6	32	5	58	3	24	3	50	0
	7	21		19		38		21		27	
	8	24		19		44		20		25	
	9	24		22		40		21		23	
14	10		8		0		6		3		4
15	11		9		5		12		2		3
16	12		9		5		9		5		3
17		43	6	26	10	68	10	16	12	47	1
18		60	4	22	6	54	8	18	3	42	3
19		41	13	27	8	48	9	19	3	64	4
20		23		15		28		18		19	
21		20		21		35		20		23	
22		21		19		31		22		20	
23	13	32	9	19	3	37	10	16	8	40	4
24	14	25	10	21	10	51	11	17	5	25	5
25	15	28	17	21	10	44	13	21	4	27	9
26		14		22		29		22		19	
27		19		21		39		28		21	
28		22		15		38		34		14	

Thirteen-year-olds

Tracking Primary Instruction

Tracking Trial Number	Auditory Task Trial Number	Subject Number 56		57		58		59		60	
1		48		46		36		38		57	
2		34		40		32		39		32	
3		32		34		28		36		35	
4		29		26		31		35		24	
5		35		28		27		26		26	
6		43		24		29		23		31	
7		24		22		27		22		26	
8		29		35		27		31		23	
9		26		24		29		23		26	
10		33		20		24		26		26	
	1		3		0		0		0		1
	2		1		0		1		1		2
	3		6		0		2		0		0
11	4	41	4	23	0	27	2	20	1	28	2
12	5	38	10	26	1	37	2	31	3	34	3
13	6	32	6	27	0	24	0	25	2	30	5
	7	24		20		29		18		28	
	8	29		18		25		20		27	
	9	23		19		20		28		25	
14	10		14		4		5		6		4
15	11		11		5		5		4		4
16	12		16		2		1		4		13
17		21	14	40	6	35	0	39	7	31	8
18		19	19	35	2	28	7	32	9	45	8
19		22	15	28	3	49	4	30	11	34	13
20		19		20		23		23		22	
21		23		16		14		19		21	
22		21		18		15		28		25	
23	13	16	14	22	2	15	3	29	7	26	10
24	14	21	19	20	1	16	2	24	8	38	8
25	15	20	15	19	2	20	6	21	9	42	11
26		20		16		12		16		25	
27		24		16		14		20		25	
28		18		15		15		23		34	

BIBLIOGRAPHY

Bahrick, H. P., Noble, M., & Fitts, P. M. Extra task performance as a measure of learning a primary task. Journal of Experimental Psychology, 1954, 48, 298-302.

Bahrick, H. P., & Shelly, C. Timesharing as an index of automatization. Journal of Experimental Psychology, 1958, 56, 288-293.

Doyle, A. Listening to distraction: A developmental study of selective attention. Journal of Experimental Child Psychology, 1973, 15, 100-115.

Gain, P., & Fitts, P. M. A simplified electronic tracking apparatus. WADC Technical Report No. 44, 1959.

Geissler, L. R. The measurement of attention. American Journal of Psychology, 1909, 20, 473-529.

Hagen, J. W. The effect of distraction on selective attention. Child Development, 1967, 38, 685-694.

Hummer, E. Über die Aufmerksamkeitsverteilung. Vierteljahrschrift für Jugendkunde, 1931, 116-121.

Johnston, W. S., Greenberg, S. N., Fisher, R. P., & Martin, D. W. Divided attention: A vehicle for monitoring memory processes. Journal of Experimental Psychology, 1970, 83, 164-171.

Kahneman, D. Attention and Effort. New York: Prentice Hall, 1973.

Kantowitz, B. H., & Knight, J. L. Testing tapping timesharing. Journal of Experimental Psychology, 1974, 103, 331-336.

Keele, S. W. Compatibility and time-sharing in serial reaction time. Journal of Experimental Psychology, 1967, 75, 529-539.

Keele, S. W. Attention and Human Performance. Pacific Palisades: Goodyear, 1973.

Kerr, B. Processing demands during mental operations. Memory and Cognition, 1973, 1, 401-412.

McLeod, P. D. Interference of "attend to and learn" tasks with tracking. Journal of Experimental Psychology, 1973, 99, 330-333.

Maccoby, E. E., & Hagen, J. W. Effects of distraction upon central versus incidental recall: Developmental trends. Journal of Experimental Child Psychology, 1965, 2, 280-289.

Mackworth, J. F. Vigilance and Attention. Middlesex: Penguin, 1970.

Moray, N. Where is capacity limited? A survey and a model. Acta Psychologica, 1967, 27, 84-92.

Murdock, B. B. Effects of a subsidiary task on STM. British Journal of Psychology, 1965, 56, 413-419.

Murdock, B. B. Measurement of retention of interpolated activity in STM. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 469-472.

Obata, J., Morita, S., Hirose, K., & Matsumoto, H. The effects of noise upon human efficiency. Journal of the Acoustical Society of America, 1934, 5, 255-261.

Posner, M. I., & Boies, S. J. Components of attention. Psychological Review, 1971, 78, 391-408.

Posner, M. I., & Keele, S. W. Time and space as measures of mental operations. Invited address, Division 3, American Psychological Association, September, 1970.

Posner, M. I., & Mitchell, R. F. Chronometric analysis of classification. Psychological Review, 1967, 74, 392-409.

Poyntz, L. The efficacy of visual and auditory distractions for preschool children. Child Development, 1933, 2, 55-72.

Thorndike, E. L., & Lorge, I. The Teachers Word Book of 30,000 Words. New York: Bureau of Publications, Teacher's College, Columbia University, 1944.

Triggs, T. J. Capacity sharing and speeded reactions to successive signals. Human Performance Center Technical Report No. 9, University of Michigan, 1968.

Welch, J. C. On the measurement of mental activity through muscular activity and the determination of a constant of attention. American Journal of Physiology, 1898, 1, 283-306.

Wundt, W. Principles of Physiological Psychology, 5th ed., translated by E. B. Titchener. New York: MacMillan, 1904. Originally published as Grundzüge der physiologischen Psychologie. Leipzig: Engelmann, 1874.