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ABSTRACT

This research investigated temporal ordering acuity in children, or the ability to perceive the first of an ordered pair of lights, or of a combined light and tone, when the interstimulus time interval within each pair became increasingly short in duration. Two group-related comparisons were made: (1) differences between slow-maturing and average kindergartners, and (2) differences between an educationally handicapped group deficient in language skills and two other groups, a normal third grade and a hyperactive EH group. In addition, task-wise correlations measured relationships of task performance within groups. Results indicated that significant differences were apparent in all tasks when the two kindergarten samples were compared; and that the slow EH group was significantly deficient in auditory and cross-modal tasks. Correlation measures suggested that: (1) Poor auditory processing and deficient intersensory functioning are correlated in slow-maturing kindergartners and the slow EH group; (2) Visual acuity is not necessarily affected by deficiencies in auditory or cross-modal areas; and (3) Auditory and visual acuity are similar kinds of capabilities for normal populations and for the hyperactive EH group who are adequate in language processing skills. The present experiment showed that a relationship exists between cognitive development and perceptual acuity in kindergarten. (Author/CK)

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Perceived Order of Auditory and Visual Stimuli in Children

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U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Regional Research Program

Abstract

PERCEIVED ORDER OF AUDITORY AND VISUAL STIMULI IN CHILDREN

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1. Abstract

Purpose: This research investigated temporal ordering acuity in children, or the ability to perceive the first of an ordered pair of lights, of tones, or of a combined light and tone, when the interstimulus time interval within each pair became increasingly short in duration.

Methodology: Two group-related comparisons were made: (1) differences between slow-maturing and average kindergartners; (2) differences between an educationally handicapped group deficient in language skills and two other groups, a normal third grade and a hyperactive EH group. In addition, task-wise correlations measured relationships of task performance within groups.

Results: Results indicated that significant differences were apparent in all tasks when the two kindergarten samples were compared; and that the slow EH group was significantly deficient in auditory and cross-modal tasks. Correlation measures suggested that (1) poor auditory processing and deficient intersensory functioning are correlated in slow-maturing kindergartners and the slow EH group; (2) visual acuity is not necessarily affected by deficiencies in auditory or cross-modal areas; and (3) auditory and visual acuity are similar kinds of capabilities for normal populations and for the hyperactive EH group who are adequate in language processing skills.

Educational Significance: The present experiment showed that a relationship exists between cognitive development and perceptual acuity in kindergarten. Unfortunately, many slow kindergartners are not ready to learn to read because of their undeveloped cognitive and perceptual processes which hinder them in grasping the meaning of successive events or of encoding them. For slow EH children between 8 and 10 years of age, the cognitive, motor and perceptual processes appear to have an uneven development, whereas the pattern of development for the slow kindergartners is more consistently low.

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CHAPTER I

INTRODUCTION

Comparatively little attention has been directed to children's time-ordering skills of auditory and visual stimuli. While language and intellectual development, as well as intersensory integration have been considered to be of primary importance in young children's ability to learn school tasks, one other skill is also basic to their perceptual and cognitive functioning: their acuity in identifying the temporal order of successive auditory or visual stimuli. Indeed, without this basic ability, children would be unable to retain and organize perceptually-received information in the correct temporal order. Not only must the child be able to register an event and to identify its nature; he must also be able to delineate its relationship with another event. The rapidity with which he can perform such a skill is a valid problem in learning and instruction, and may be a reflection of how effectively his perceptual and cognitive processes function when comprehending complex symbolic stimuli.

The Problem

The purpose of this study was to examine school children's time-ordering skills with a pair of high and low pitch tones, a pair of red and green lights, or a pair consisting of a sound and a light, that is, the manner in which they could perceive and identify what followed what when the members of a given pair occurred rapidly. The term acuity in identifying temporal order refers in the present study to the minimum interstimulus interval between two successive stimuli in tasks where the child is able to delineate the first of two successive stimulus signals (red or green light for the visual pairs, a high or low pitch tone for the auditory pair, or a light or a tone for the combined modality pair).

Previous studies have suggested that aphasic patients with known lesions in the hemisphere commonly used for language processing not only have definite deficiencies in receptive and expressive language; they also are significantly slower than normal subjects in their acuity of identifying which of two tones occurs first (Holmes, 1965; Efron, 1963).

If differences are known to occur in ordering skills of high and low pitch tones when the functioning in the "language" hemisphere of the brain is acutely abnormal (as in aphasics), do differences also appear to a lesser degree when cerebral functioning is undeveloped? The term "undeveloped" in this sense refers to sensory and cognitive immaturity in a normal young child of kindergarten age, or to a minor cerebral dysfunction in an educationally handicapped child approximately nine years of age.

Two problems were pertinent to the present study. The first considered differences in behavior between slow-maturing and average kindergartners from a normal population. The second question considered differences in behavior between older subjects, approximately nine years of age, who had known dysfunctions in auditory-language processing, and normal subjects attending the regular classroom.

More specifically, in reference to the first question, the purpose was to analyze and compare one aspect of kindergartners' sensory and cognitive development. Up to the first grade, some children are slower in their motor development, and may have difficulty in skipping, hopping, and articulating words. Others may have difficulty in ordering sounds or words without reversals. Still others may be slow in integrating events in one modality with symbols in another (as, for example, relating a visual symbol with a specific sound, or vice versa). Finally, others are deficient in language skills, due to environmental language deprivation. The first problem, then, was to see if differences also occurred between slow-maturing and average kindergartners in their ability to designate which of an ordered pair of nonverbal stimuli occurred first. That is, would deficits in temporal ordering acuity show up from a maturation standpoint in the crucial period just before the child enters the first grade? Would children who appear to be immature in copying skills, in "draw a man" conceptualization, and in general cognitive development related to language concepts also be deficient in the perceptual skills required in the nonverbal tasks of this experiment?

The second focus of this study concerned educationally handicapped children, or those with "learning disabilities." Here, the aim was to determine relationships in the specified tasks between educationally handicapped children (with known deficits in auditory-language skills) and a normal group of children of comparable age levels. In this connection, the primary goal was to specify the nature of performance between the two groups of children, in order to determine if minor cerebral deficiencies affecting language skills in educationally handicapped children affected their acuity in perceiving and ordering pairs of nonverbal stimuli.

With both the slow-maturing kindergarten group and the educationally handicapped sample with auditory-language problems, the intent was also to investigate task-related differences: if these children were particularly deficient in ordering a pair of sounds, when this task was compared to that of ordering a pair of lights.

Hypotheses

The present study was concerned with three major hypotheses:

1. Slow-maturing kindergartners when compared to average kindergartners will be significantly deficient in the ability to order in quick succession pairs of lights, tones, or a tone and a light.

2. Educationally handicapped children with problems in auditory-language areas will be significantly deficient in the ability to order tones in quick succession when compared to a normal population of comparable age.

3. The auditory task will be more difficult than the visual for the two slow-maturing groups (kindergarten and educationally handicapped) but not for the average groups.

In addition, correlation measures were sought between tasks: auditory and visual, auditory and cross-modal, and visual and cross-modal, in order to find the extent to which underlying tendencies and relationships were present for average-performing and slow-maturing populations.

CHAPTER II

RELATED RESEARCH

Neurological Implications

Temporal judgment, which is the judgment of serial order, requires that a subject be able to designate which of two successive stimuli comes first. Hirsh (1959) found that normal adult subjects trained to perform the task could make such a judgment equally well for visual and auditory stimuli. He hypothesized that temporal ordering judgments derived from a central processing ability in the brain.

Efron, a neurologist, was faced with the problem that many of his aphasic patients with known lesions in the temporal lobe of the dominant hemisphere (the "language" area of the brain) could not understand speech, and were deficient in sequencing ability. While the normal adult requires around 60 msec. to separate sounds and give a correct report of which one occurs first, Efron found that his aphasic patients required as much as a second between two brief 10 msec. sounds of very different frequencies before they could identify correctly the temporal order (Efron, 1963). Similar experiments have been made on aphasics by Edwards and Auger (1965), Holmes (1965), and Lowe and Campbell (1963); in each case, it was found that aphasics as a group were significantly deficient in auditory sequencing.

It should be qualified here that mention of these neurologically oriented research studies with abnormal patients in no way implies that any of the educationally handicapped subjects in the present study may have a lesion in any one area of one particular cortical hemisphere, or, for that matter, be aphasic. Such is clearly not the case, and such hypotheses would have no solid foundation at all. What these related research studies provide is circumstantial evidence that deficiencies in certain kinds of nonverbal patterning tasks are correlated with disturbances in the dominant ("language") hemisphere of the brain in aphasic patients. The implication is that these same tasks may also be correlated with certain types of slow maturational development in children. However, even at the present time, very little is understood regarding the underlying physiological mechanisms dealing with sequential patterns in humans.

The ability to discriminate single pitch tones has been analyzed as a peripheral sensory function, deriving from lower cortical areas (Whitfield, 1967). However, the ability to analyze the temporal order of two tones is a higher-level intellectual act, presumably involving the higher cortical brain processes and language (cf. Lashley, 1951; Hirsh, 1959). A parallel can be made in psychological and operational terms. If a child can discriminate and match one pitch sound separately, and then another sound after the first one has been identified, this is a lower-level discriminatory process. If, however, he can analyze the two tones consecutively sounded in terms of their serial order, then this is a higher-level intellectual skill. In language the same parallel can be made. If the child recognizes phoneme by phoneme at a given instant, the single stimulus standing by itself has little meaning and no sense of pattern. However, if he can connect and interpret the meaning of consecutive phonemes, he is now comprehending a pattern and the relationship of its components. This is a higher-level intellectual skill, and involves higher-level cortical functioning (Luria, 1966).

Auditory Discrimination as a Factor in Reading Ability

A study of the literature of poor reading in the early grades indicates that poor auditory discrimination and reading retardation go hand-in-hand. De Hirsch and Jansky (1968) found this to be true with reading disabilities; Deutsch speaks of such a correlation among the culturally deprived (1964); and Wepman (1960) found that more than a fourth of the non-readers in the first grade were inadequate in auditory discrimination. In each case, the term "auditory discrimination" was not used in reference to pairs of pitch tones as in the present study, but in reference to digit span memory and verbal sounds.

Speech as a Factor in Developing the Child's Perceptual and Cognitive Processes

The Russian psychologist Leont'yev (1969) has hypothesized that the discrimination between speech sounds or between musical tones, which appears to be an elementary kind of capability at first glance, is formed through environmental influences as the child acquires language or reproduces music (p. 429). Luria (1959), another Russian psychologist, also stresses the importance of speech in developing the child's general perceptual and cognitive processes. He writes:

> The fact that the word is included in the context of nearly all basic forms of human activity, that it participates in the formation of perception and memory in stimulus and action, permits a new approach to an important region of mental activity. (p. 14)

Luria wrote of research in the Soviet Union "which showed convincingly not only that the word is gradually excluded from other complexes perceived by the child, but also the decisively important fact that, under its influence, the young child's perception and memory acquire new features; by allowing him to distinguish the essential features of an object the word makes his perception of objects generalized and constant and creates new possibilities for the development of coherent, differentiated memory" (1959, p. 17).

In short, educational and psychological research studies cited suggest that lack of development of the speech processes in the early years of a child's life may be correlated with lack of development of perception and also of auditory discrimination.

Pitch Discrimination versus Color Discrimination Developmental Consideration

From a developmental standpoint it has been found that color discrimination in children develops at an early age with little training, whereas pitch discrimination develops at a later age and is more subject to instruction and maturation factors (cf. Wohlwill, 1960; Petzold, 1966; Schevill, 1969). Therefore, it would be expected that young children, having seen the red and green colors used in the present experiment many times in everyday experience, would be more adept at perceiving their temporal order than they would be at perceiving successive high and low pitch tones. In order that young children recognize high and low pitch tones at all, they must be classified by association with a specific color, spatial position, or label. Jeffrey (1958) found the spatial method successful with preschool children of associating one end of a piano keyboard with a high tone, and the other end with a low tone. The verbal labels of "high" and "low" are too sophisticated a concept for young children. McGinnis (1928) found that such labels as "Daddy Bear" for the low tone and

"Baby Bear" for the high tone could help preschool children to identify the respective tones.

In sum, then, related research suggests that the present study is dealing with a higher-level cortical function and intellectual skill in the task of making a choice of the serial order of two consecutive visual or auditory stimuli. What is implied in the literature is that for successful performance not only the element of discrimination is important, but also the level of ability in auditory-language processing. This has not been investigated in children with reference to temporal ordering skills of lights or of pitch tones. What was needed was a systematic analysis and comparison of various populations of young children in the three tasks of auditory, visual, and combined auditory-visual serial ordering. To these ends, therefore, the present research was developed.

CHAPTER III

PROCEDURE

Sample

The sample for the present research included a total of 124 subjects from five groups of children:

30 average kindergartners
32 slow-maturing kindergartners
30 normal third graders
22 educationally handicapped children between the ages of 8 and 10-1/2 with auditory-language problems (slow EH group)
10 hyperactive educationally handicapped children without auditory-language problems (hyperactive EH group)

The present research was conceived as an intensive study of the sensory behavior of these populations. The assumptions were that significant differences would occur in acuity of serial ordering skills between the slow-maturing and average kindergarten groups; and, again, between the slow EH group and the normal third grade. In task-wise comparisons, the hypothesis was that there would be extremely low correlation between the auditory and visual tasks within the slow kindergarten group and the slow EH group, but not within the other groups. The hyperactive educationally handicapped group (N=10) was used as a small control sample in comparison with the EH group with auditory-language problems and also with the normal third graders. No hypotheses were made about this hyperactive EH group.

All the kindergarten subjects and third grade subjects were selected from schools in the Mount Diablo School District, West Pittsburg, California. The specified schools for all but the EH population were in the River Compensatory Area, a depressed area federally funded by a Title I project. This area was selected for the present research for two reasons: because of the significant proportion of children who were considered "slow maturing" at kindergarten age, and because of the exceedingly rich data available on every child in the program. For example, each kindergartner took a pre- and a posttest, given by learning sr cialists in the school, on the Metropolitan Readiness Test, ..ie ABC Inventory, the Santa Clara Inventory, the Bender-Gestalt "Draw-a-Man," and the Riley Articulation and Language Test.

The third grade sample for the present study was originally 60 subjects: 30 of average or above-average IQ; and 30 below grade level in reading ability. However, since there was no difference at all between the two groups in the acuity of serial ordering for lights or sounds, a randomized sample was drawn from the combined groups to equal the 30 members used in the present study. This group was used as the normal control sample, as opposed to the EH group of comparable age level.

Educationally Handicapped Subjects

All educationally handicapped subjects were selected from the Treat Learning Center, a public school in the Mount Diablo School District, devoted especially to specialized instruction for the educationally handicapped.

Ages. The mean ages of the kindergarten samples were:

1. slow-maturing K — 73 months
2. average K — 72 months

Mean ages of EH groups:

1. slow auditory processing — 115 months
2. hyperactive group — 113 months

Third grade control group: 110 months

Sex differences. Among both kindergarten samples and the normal third grade control group there was an equal distribution of boys and girls. However, among the combined EH groups, totaling 32, there were only 4 girls. By far the greater proportion of EH subjects are boys. Thus, the unequal proportions in the EH sample.

Method of Selecting Subjects: Standardized Tests

The average kindergartners were randomly selected from a larger sample of children from three schools. The final criterion for selection was that they score 50 percentile or above on the Metropolitan Readiness Tests. The slow-maturing kindergarten sample also was randomly selected from a larger population of children scoring below the 50th percentile on the Metropolitan Readiness Tests. The Metropolitan Readiness Tests include both verbal and nonverbal measures: word meaning, listening (the ability to comprehend phrases instead of individual words), visual perception involving recognition of similarities, copying, and number knowledge. It should be qualified here that 7 of the total 32 low-scoring kindergartners received scores in the mid- to low 40's on the Metropolitan Readiness Tests. These scores were considered a low average (low "C") as far as grade level was concerned. The remaining slow-maturing kindergartners (N=25) were all indeed "slow-maturing" not only in being behind grade level on the Metropolitan Readiness Tests, but also well below age level on the "Draw-a-Man" and the ABC Inventory.

The slow EH subjects were screened according to their failing scores on certain ITPA (Illinois Test of Psycholinguistic Abilities) subtests. These subtests were: auditory-closure, auditory association, grammatical closure, and digit span memory. Examples of items from these subtests on which all EH subjects in this group failed were:

"Soup is hot, ice cream is _____."
"This is Jamie's bike: it is ____."
"Fill in the missing sounds: new_pa_er."

The hyperactive EH children (N=10) were selected (1) if they had formerly been diagnosed as EH children and were in classes with definite learning problems; and (2) if they scored grade level or above on the ITPA subtests which the other EH group had failed. All 10 subjects were receiving medication for hyperactivity.

Third graders were given standardized tests similar (but not identical) to the ITPA). It is important to note that one-third of this group were slightly below grade level in reading ability, even though they did not have any minimal brain damage as did the two EH samples. Third graders' tests pertained mainly to reading comprehension. No record is available on how they would perform on the ITPA subtests.

Testing Procedure

Each child was tested individually on two separate occasions by the examiner in order to ascertain the he fully comprehended his task. Preliminary to the actual testing of the visual task, the child was given the opportunity to "make the red light flash on first" at the back of his desk by pressing a button on a small electronically geared box. Similarly he could press another button for the green light first. This preliminary practice, very enjoyable for the child, was given in order to ensure that he knew the concept of "first" when successive pairs of stimuli were presented.

Once the association of temporal order was made, the examiner took the little box from the child and pressed the stimulus signals slowly at first (around 1000 msec.), and then with increasing rapidity. The interval between the presentation of each pair of stimuli was approximately four seconds. The child simply had to point to the light which flashed first. For each rate (600, 400, 250, 175, 125, 100, 80, 60 msec.) the pairs of stimulus signals were given six times, at times with the red light flashing first, at other times with the green first. The child's own fastest interstimulus interval, based on 100% for six trials, determined his score.

A similar procedure was followed for the sounds. This time the child had in front of him two resonator tone bells, put out by Scientific Music Industries expressly for public school use. One bell, lower in tone (middle C) was fairly large in size and was red and white in color. The other bell, an octave and a half higher than middle C (high F#), was fairly small in size and was red and black in color. In other words, the tones differed in size, color, pitch, and even in overtones. Identical stimulus tone bells were placed in a half-open suitcase in a concealed area in the room, and were manipulated by the electronic equipment in the examiner's hand. If E pushed one button, one bell would sound automatically by a mallet in the concealed area. The child would then try to match the sound with one of his own two tone bells. In addition to differences in sound, he could associate differences in size, color, and spatial position with each of the two sounds. The high tone which he matched with his own red and black tone bell was always placed to the right; the child's own low tone bell was always on the left. At first the child struck with his own mallet whichever tone bell matched the one being sounded elsewhere in the room. As soon as he had learned to associate the size, color and position with each kind of sound, the task was changed. Now the mallet was taken from the child substituted by two telegraph keys. To the left of one key was placed the low tone bell; to the right of the other key was placed the high tone bell. Now the child's response was silent. All he had to do was to push a response key <u>representing</u> the stimulus tone. He now had to rely on his own tonal memory and color-size-spatial association in pressing the two respective telegraph keys. For <u>each</u> stimulus tone a pressure on the response key was required. Although the stimulus presentation was electronically timed, the rate was slow enough for most children to interpret separate tones.

As many as 30 single stimulus tones were given to the child in such a fashion, first to ensure that he had indeed learned to make the intersensory association of a specific object with a specific sound; and secondly as a measure of his sustained attention span. However, the lowest criterion level for success was six correct out of six impulses.

Now that the discrimination of single pitch tones was established, the pairs of tones were presented to the child. First, it was important that he understand the concept of temporal order with sounds as well as with vision. The examiner would ask the child to "make this one come first," or "now make this one come first." It was sometimes apparent that the child could voluntarily strike the two educator tone bells in a specific order, and indeed had the concept of temporal order per se, but was unable to discriminate which sound came first when he had to rely on the auditory part of the task. (See the following page for the outlined task analysis of all the tasks.)

All of the tones as well as the lights were electronically gauged in tempo, starting at one-second intervals, and gradually increasing in tempo to as fast as 60 msec. between the two tones if the child was able to discriminate the tones at this quick rate. Occasionally, at the other end of the continuum the interstimulus interval had to be extended to 1600 msec. in cases of abnormally slow processing. The child's own fastest successful interstimulus interval, based on 100% for six trials, determined his score.

If the subject was unable to achieve a perfect score within six trials at one specific rate, then six more trials were given at the rate nearest the one on which he had just failed. In other words, each child was not taken through the whole sequence of interstimulus rates, but only through one of the specified digits beyond his own criterion level. At each interstimulus rate, six trials were given, three for one member of the stimulus pair occurring first, and three for the other member, randomly arranged.

In each case in the ordering tasks the subject simply pointed to one or the other of his own tone bells as a means of indicating which tone bell, concealed from sight, was sounded first. Practically no conversation went on during this whole procedure, since the discrimination process was learned primarily by a conditioning technique. When the pairs of stimuli occurred at too fast a rate for the child, he simply guessed, or stated that they were too fast. Then the next slower rate was tried once more as a final criterion level.

NAME ______________________
AGE ________
GRADE ________

ABC INVENTORY MA ________
RUTGER DRAWING MA ________
OTHER ________________

TASK ANALYSIS OF PERCEPTUAL SKILLS INVOLVING TWO LIGHTS OR TWO TONES

I

Simple Discrimination Tasks

1. Matching Stimuli

   a. Striking appropriate tone bell after each successive stimulus. Pass Fail

   b. Pressing appropriate button after each successive flashing light. Pass Fail

2. Discriminating separate tones or lights by pressing one or the other response button. (Demonstrates concept of "same" and "different.")

	Number Correct			
	0-15	16-20	21-25	26-30
Tones				
Lights				

II

Categorizing Pairs or Chains of Stimuli

1. Demonstrating and understanding "first" and "second" by ordering two tone bells, two lights, or a light and a tone.

	Pass	Fail
Tones		
Lights		
Light/Tone		

2. <u>Criterion Task</u>
   Applying verbal concept of "first" to perception by pointing to first tone heard and first light flashed. Quickness of perception in msec.

   Tones ________
   Lights ________
   Light/tone ________

3. Reproducing longer patterns containing two lights or two tones.

	2	3	4	5	6
Tones					
Lights					

The third task, consisting of a bell and a light, was given in a similar fashion, until the criterion level of six perfect responses was reached at the subject's own fastest interstimulus rate. This time the child had to listen and look at the same time, and to assess whether the bell or the light occurred first.

Comparison of Visual and Auditory Tasks in Terms of Sensory Organization

The criterion for the visual task required essentially that the child point to one of two lights that flashed on first. In addition to temporal ordering, the child had as a focus of identification spatial ordering. That is, the red light was always on the left, the green light on the right. All verbalization was discouraged in the final criterion response, in the event that the verbal naming might be especially difficult for some of the slow-maturing or brain-damaged subjects. In essence, then, in the visual task the response required visual-spatial delineation. With the pairs of pitch tones, however, the response was not an auditory one, but again a visual-spatial one. Stated simply, the child now had to learn that one particular visual object (a red and white tone bell, placed at the left of the table) represented one sound he had just heard coming from elsewhere in the room, and that another particular object (a red and black tone bell, placed at the right of the table) represented the other sound. Percepts of sound were now transferred to percepts of color and spatial position. (No mention ever made of the concept of "high" and "low" tones.)

For the third task, which combined a sound and a light in succession, the complexity of the task lay more in the ability to attend to two different kinds of modality dimensions successively than in the ability to associate specific visual objects with the stimuli. That is, the young child was presented with both a sound and a light, and for some it was too difficult to focus attention on both. They would either attend to the bell or to the light, no matter which one came first.

The auditory task and the light/tone task had cross-modal elements in them. The term "cross-modal" implies here a response in a different sensory modality than the one used for the stimulus. The auditory task involved a cross-modal transfer from the auditory to the visual modality, whereas the auditory-visual task involved an alternate shifting of attention to stimuli in two modalities, auditory and visual. It is apparent that the visual task involving an "ipsi-modal transfer" (that is, the same modality in the response as in the stimulus) was relatively simple, compared to the auditory and combined light/tone tasks, which required more complex intersensory or "cross-modal" integration.

Instrumentation of Testing

A system of switches generated impulses for each set of stimulus conditions. Both the time between the onset of stimuli and the interstimulus intervals were systematically controlled with high precision by the electronic stimulus generator, designed expressly for the experiment by Nurmia of the Lawrence Radiation Laboratory at the University of California in Berkeley. Time intervals were altered digitally, according to dial settings manually adjusted by E at the beginning of each trial of six pairs of stimuli. For interstimulus intervals beyond 1500 msec. the stimulus signals were generated manually, and recorded on a two-channel tape recorder. These slow responses were transcribed later from the tape to a Brush Chart record for visual analysis of exact interstimulus intervals.

For the visual stimuli, two separate lights (red and green), mounted side by side, were flashed on in either order. Manipulation of the rear panel of the stimulus generator permitted adjustment of the lights, that is, that they occur either singly or in pairs, or one light alternating in quick serial order with a pitch tone. The green light was always on the right, the red on the left. One small box, connected electronically to the stimulus generator, fitted neatly into the hand of E for the stimulus pressure. In addition, all that was necessary was a flip of a switch on the back of the stimulus generator to change the stimulus signals from lights to tones or to a combination of a light and a tone.

The auditory stimuli, Tone Educator Bells, were fitted on a heavy metal base in a suitcase. Mallets automatically struck the tones either singly or in pairs, according to the adjustment on the stimulus generator which was electronically plugged in from the bell mechanism and the pressure of one button in E's hand. In addition, the child had in front of him a duplicate set of tone bells and his own mallet, as means of reinforcing the sound image before the actual testing began. The specified stimulus pair was automatically sounded after approximately a four-second interval. The subject simply indicated his choice by pointing to the one which he thought occurred first.

Presentation of the Sequencing Tasks

All tasks were administered on two separate occasions. The first session was considered a "practice" session, and the second session the actual testing session. Scores of the second session were used in the final computation. No child did worse on the second occasion, although some children performed considerably better during the second testing than the first. During the first session, the child performed the visual, auditory, and, last of all, cross-modal task. During the second session the order of the auditory and visual tasks was reversed; however, the cross-modal task was always given last, since it often appeared excessively complex for some slow-maturing or brain-damaged subjects.

Failure To Identify Single Pitch Tones

In a very few instances (3 slow-maturing kindergartners out of a total of 32; and 2 EH subjects out of a possible 22), the children were simply unable to discriminate separate tones. Even with extended practice, these children made errors in associating the separate high or low pitch tones with the tone bells in front of them. Their criterion level was to distinguish six single pitch tones by matching the sound to the visual replicas of the sounds which they had just heard. Ironically, 3 out of these 5 failing children were able part of the time to reproduce pairs of tones accurately on the tone bells in front of them, even though they had difficulty in matching one single tone or pointing to which one of a pair came first. The hypothesis is offered here that the spatial-motor movement necessary to play the pairs of tones seemed to come naturally and intuitively. However, what was lacking was their intersensory organization and their analytic ability to successfully perform the task. Thus, the ability to play the pair of tones, but not to match single tones or to point to the first of a pair heard. It was not established whether these subjects were "tone-deaf," whether their intersensory development was immature, or whether their whole analytical and discriminatory sense was insecure. Such tonal disabilities were not apparent in the average kindergarten sample or in the normal third grade.

Length of the Testing Periods

The length of each testing session varied according to the child's own acuity. If he was average in capabilities, the session lasted as little as 20 minutes. For a few EH subjects, the sessions sometimes extended up to an hour, with short intermissions.

Supplementary Testing

All kindergartners received separate testing of the "Draw-a-Man," ABC Inventory, Riley Articulation Test, and the Metropolitan Readiness Test. Third graders were tested on standardized IQ measures, but since all of the sample did equally well whether they were of high or low IQ, their test scores were not used as a variable in the present experiment. The educationally handicapped were all tested on the ITPA. Individual members of the EH group were also tested on the WISC and Stanford-Binet as well.

Summary

Efficiency of temporal ordering of lights and pitch tones occurring in rapid succession was examined in five subject groups: (1) slow-maturing kindergartners, (2) average performing kindergartners, (3) normal third graders, (4) educationally handicapped children with known auditory-language problems, and (5) a hyperactive EH group without language processing deficits.

The experimental procedure yielded a measure of each child's acuity for identifying what followed what in time under three stimulus conditions involving a high and low pitch tone, a pair of red and green lights, and a cross-modal (light and pitch tone) pair. Acuity of performance was assessed by the time in msec. separating the two members of the ordered pair; that is, the interstimulus rate required for accurate discrimination of the first pitch of a pair; or the first light of a pair; or a light or a pitch tone of a pair occurring first. In addition, all subjects were tested on standardized verbal and nonverbal measures, as a basis of designating in which group they should be classified in the present experiment.

CHAPTER IV

RESULTS

Significant findings were apparent in reference to both the slow-maturing kindergartners and the EH subjects with auditory-language deficits. The slow-maturing kindergarten sample was significantly slower than the average kindergarten group in all three tasks--pitch, lights, and the combined light/tone task. The slow EH group was significantly slower than the normal third grade in both the auditory and the combination light/tone task, but not in the visual one. No significant differences were apparent between the average kindergarten and third grade populations, nor between the hyperactive EH group and the normal third grade, or for that matter between the hyperactive EH group and the slow EH group with auditory-language deficits.

A task-wise comparison within groups suggests that the auditory task is more difficult than the visual for the slow-maturing kindergartners and the slow EH group of children. Such differences between auditory and visual tasks did not appear within the other groups, that is, within the average kindergarten, third grade, or hyperactive EH groups.

The following is a detailed analysis of how the groups performed on each of the three tasks.

Pitch Differences

Slow-maturing kindergartners showed a definite deficiency in their ability to perceive which of a pair of pitch tones came first. Fourteen subjects out of a total 32 were simply unable to distinguish the first sound in a pair, no matter how slowly the two sounds were played. Since such a large proportion would have to be deleted from an analysis of variance because of no numerical score to indicate their failure, it was decided to analyze the performance of the whole group of slow kindergartners in terms of successful performance (that is, at an interstimulus rate under 600 msec.); slow performance below criterion level (that is, at 600 msec. or even more slowly), and a failure or inability to perceive which of a pair of tones came first. Chi-square analysis in

Table 1 shows a significant difference between the two groups of kindergartners in the number of subjects who could successfully perform the pitch task and the number who could not.

TABLE 1

CHI-SQUARE ANALYSIS COMPARING TWO KINDERGARTEN SAMPLES IN ACUITY OF PERCEPTION IN THE PITCH TASK

	Slow-maturing K		Average K		Total	
	No.	%	No.	%	No.	%
Could do successfully at an interstimulus rate under 600 msec.	9	28	25	83.3	34	55
Could do, but only very slowly, 600 msec. or longer interval in interstimulus rate	9	28	5	16.7	14	23
Could not tell which sound came first at all	14	44	0		14	23
N =	32		30		62	

$x^2 = 21.51$*

*Significant beyond .01 level.

Of the 14 slow-maturing kindergartners failing the pitch task, all but 3 could discriminate and match the sounds of single tones to the tone bells placed in front of them. In other words, they could discriminate each of the two specified tones when they were sounded separately, but were unable to indicate which of two tones sounded first when they occurred one after another. This inability to integrate two sounds in a meaningful sequence when they occurred one after the other was present even when the interval between the tones was comparatively long (over 1-1/2 seconds). Yet all of the children comprehended the concept of order. They could voluntarily play one tone bell before another, yet could not discriminate the sound sequence when someone else performed such a task.

The slow EH group with auditory-language deficits was also significantly deficient in the pitch ordering task. Of the 22 children in this sample, 5 were unable to perform the sequencing task. The 17 remaining subjects in this low-scoring EH group could identify the order of a pair of tones, but only if the second tone came at an abnormally slow rate after the first one. It is interesting to compare the mean average of the interstimulus rate of these EH children who could perform the auditory task, however slowly (that is, the remaining 17 out of a possible 22 subjects) with that of the portion of the slow-maturing kindergarten sample who were also able to distinguish the two tones consecutively (18 out of a possible 32 subjects). Table 2 shows these mean scores.

TABLE 2

MEAN SCORES IN MSEC. OF THE FIVE GROUPS IN THE PITCH TASK

(This is the task which requires a designation of the first of a pair of high and low tones sounded consecutively.)

	No. of Subjects	Mean	S.D.
Average K	30	400.34	404.35
Slow-maturing K	(18 out of a possible 32)	715.79	651.29
Slow EH with auditory-language processing deficits	(17 out of a possible 22)	791.18	507.21
Hyperactive EH	10	230.0	182.48
Average third grade	30	219.33	171.48

Both slow groups show mean scores over 700 msec. for the time interval between two tones. If an absolute score could have been obtained for all the subjects in these slow-performing groups, rather than only a portion who could be given a numerical score, the final mean scores would have been even slower and more indicative of their real deficits in this sequencing task of pitch tones.

Table 3 shows an analysis of variance comparison among populations in the pitch ordering task. Significant differences appear between the slow EH group and the average third grade. Since all the failing slow-maturing kindergartners were deleted from this analysis (14 in number, or 44% of that sample), no significant differences were apparent between the remaining slow kindergartners who could perform the task and the average kindergartners. Nevertheless, the deficits of the low-scoring kindergarten group were significant in the pitch task, as has been previously shown in Table 1.

TABLE 3

ONE-WAY ANALYSIS OF VARIANCE, SHOWING DIFFERENCES AMONG THE FIVE GROUPS IN PERFORMANCE OF THE PITCH TASK

Source	SS	df	MS	F
Between groups	5,421,900.0	4	1,355,500.0	7.69*
Within groups	17,449,000.0	119	176,250.0	
Total	22,870,900.0	123		

$p < .01$ U=.2371

One-Way Analysis of Variance, Scheffe Tests

Comparison	Groups		Means		Minimum Scheffe	Significance
	A	B	A	B		
1	1	2**	400.345	715.789	-777.747	NS
2	1	3	400.345	791.176	-869.282	NS
3	1	4	400.345	230.000	-427.313	NS
4	1	5	400.345	219.333	-226.883	NS
5	2	3	715.789	791.176	-598.302	NS
6	2	4	715.789	230.000	-148.025	NS
7	2	5	715.789	219.333	37.214	Yes*
8	3	4	793.176	230.000	-84.511	NS
9	3	5	793.176	219.333	96.349	Yes*
10	4	5	230.000	219.333	-548.628	NS

Key to groups: 1 = average K; 2 = slow-maturing K; 3 = slow EH; 4 = hyperactive EH; 5 = third grade.

*Significant at or beyond the .01 level.

**Based on 18 out of a total sample of 32, since 14 (44%) were unable to perform the task.

Differences among Kindergartners, Third Graders, and Hyperactive EH Subjects

There were no significant differences between the average kindergarten sample and the third grade. Although children appear to gain facility in identifying auditory sequences as they grow older, the gain is not significantly greater. In addition, no significant differences appeared in the hyperactive EH group in comparison with the slow EH group, or in comparison with the normal third grade. In fact, the hyperactive sample of EH subjects was comparable in performance in the auditory task to the average third grade.

Light Task Differences

Judging from a comparison of scores within populations, the light task was not as difficult for the two slow groups as was the pitch task. That is, the mean interstimulus rate between two successive lights could be much smaller, and the lights recognized, than for two successive tones. Furthermore, only 3 subjects in the whole experiment failed to be able to tell which of two lights came first; that is, 29 out of 32 slow-maturing kindergartners could perform this task, however slowly. This is noteworthy especially in comparison to the pitch task: 44% failure of the slow kindergarten group and 23% failure of the slow EH group.

Table 4 shows the mean scores of five groups of subjects. Although the figures themselves may mean little to the reader, if one could witness the actual rapid succession of the red and green lights in the milliseconds described, the difference among populations would be more striking. It is gratifying to observe that average children, even of kindergarten level, can perceive and interpret the flashing of two lights when they occur in extremely rapid succession. A few average kindergartners were even able to perceive the successive lights at 60 msec. intervals. This rate is as fast as the normal adult rate (Efron, 1963).

Table 5 shows the analysis of variance comparisons. The slow-maturing kindergartners were the only subjects who were significantly slower than three other groups. (They were significantly slower than the average kindergartners as well as third grade and hyperactive EH subjects.) The slow EH group with auditory-language problems was slow, but not significantly so, in performing this task.

TABLE 4

MEAN SCORES IN MSEC. OF THE FIVE GROUPS IN DESIGNATING WHICH OF TWO LIGHTS OCCURS FIRST WHEN FLASHED IN RAPID SUCCESSION

	Mean	S.D.
Average K	121.00	68.09
Low-maturing K	279.37	144.04
Slow EH with auditory-language problems	191.82	143.48
Hyperactive EH	121.00	61.18
Average third grade	86.33	43.35

TABLE 5

ONE-WAY ANALYSIS OF VARIANCE SHOWING DIFFERENCES AMONG FIVE GROUPS IN THE LIGHT TASK

Source	SS	df	MS	F
Between groups	697,390.0	4	174,350.0	15.98*
Within groups	1,298,200.0	119	10,909.0	
Total	1,995,590.0	123		

$p < .01$ U=.3495 F value = 3.48

TABLE 5 (cont.)

One-Way Analysis of Variance, Scheffe Tests

Comparison	Groups A	Groups B	Means A	Means B	Minimum Scheffe	Significance
1	1	2	121.000	279.375	-257.406	Yes*
2	1	3	121.000	191.818	-180.199	NS
3	1	4	121.000	121.000	-142.292	NS
4	1	5	121.000	86.333	-65.949	NS
5	2	3	279.375	191.818	-20.368	NS
6	2	4	279.375	121.000	17.199	Yes*
7	2	5	279.375	86.333	94.010	Yes*
8	3	4	191.818	121.000	-77.801	NS
9	3	5	191.818	86.333	-3.896	NS
10	4	5	121.000	86.333	-107.626	NS

Key to Groups: 1 = average K; 2 = slow-maturing K; 3 = slow EH; 4 = hyperactive EH; 5 = average third grade.

*Significant at or beyond the .01 level.

Combined Light and Tone

The combined light and tone task required that the child indicate whether a light or a tone came first when the two stimuli occurred in rapid succession. Not only was the child required to look at the light that might be flashed on; he also had to listen for a sound (the pitch tone) and indicate whether the light or the tone came first. This task was significantly more difficult for both the slow-maturing kindergartners and the slow EH children with auditory-language deficits. Table 6 shows the mean scores of the five groups in this task. Table 7 shows the results of a one-way analysis of variance.

TABLE 6

MEAN SCORES IN THE COMBINED LIGHT/TONE TASK

	Mean	S.D.
Average K	313.79	140.65
Slow-maturing K	642.86	480.70
Slow EH with auditory-language deficits	528.64	382.59
Hyperactive EH	223.00	83.94
Average third grade	200.00	113.29

TABLE 7

ONE-WAY ANALYSIS OF VARIANCE FOR THE COMBINED LIGHT/TONE TASK

Source	SS	df	MS	F
Between Groups	3,282,500.0	4	820,630.0	10.11*
Within Groups	8,684,800.0	119	81,166.0	
Total	11,967,300.0	123		

$p < .01$ U=.2743 F value = 3.48

TABLE 7 (cont.)

One-Way Analysis of Variance, Scheffe Tests

Comparison	Groups A	Groups B	Means A	Means B	Minimum Scheffe	Significance
1	1	2	313.793	642.857	-633.632	Yes*
2	1	3	313.793	528.636	-515.369	NS
3	1	4	313.793	223.000	-299.006	NS
4	1	5	313.793	200.000	-163.012	NS
5	2	3	642.857	528.636	-210.059	NS
6	2	4	642.857	223.000	11.464	Yes*
7	2	5	642.857	200.000	140.429	Yes*
8	3	4	528.636	223.000	-99.752	NS
9	3	5	528.636	200.000	30.279	Yes*
10	4	5	229.000	200.000	-365.129	NS

Key to Groups: 1 = average K; 2 = slow-maturing K; 3 = slow EH; 4 = hyperactive EH; 5 = average third grade.

*Significant at or beyond the .01 level.

Comparison Among the Three Tasks

Table 8 shows a summary of the mean scores of each of the five groups on each of the three specified ordering tasks. This measure may be considered an indication of the child's acuity in perceiving successive stimuli, that is, his own criterion level of the smallest time interval between two stimuli required in order to indicate which one of the pair comes first. An inspection of these scores shows the marked difference in perceptual acuity between the auditory and visual tasks for the two slow populations: the slow-maturing kindergartners and the slow EH sample with auditory-language deficits. Such striking differences among the three tasks are not so apparent within the other three populations: average kindergartners, third graders, and hyperactive EH subjects.

TABLE 8

MEAN SCORES IN MILLISECONDS SHOWING ACUITY OF PERCEPTION IN DISCRIMINATING THE FIRST MEMBER OF A PAIR OF STIMULI (Three tasks: lights, pitch tones, and combined pitch tone and light)

Group	Lights	Tones	Combined Light/Tone
Slow-maturing K (N=32)	279.37	715.79 (18 out of a possible 32)*	642.86
Average K (N=30)	121.00	400.34	313.79
Slow EH with auditory-language deficits (N=22)	191.82	791.18 (17 out of a possible 22)*	528.64
Hyperactive EH (N=10)	121.00	230.00	223.00
Average third grade (N=30)	86.33	219.00	200.00

*The remainder of these samples failed the task and had no mean scores to compute.

A close inspection of the data also suggests that the hyperactive EH subjects were as acute as normal children of comparable age in their discriminations. In fact, of the 10 children in this group, 2 were tested by E on a day when they had no sedation. (The nurse had run out of the prescribed drugs on that particular morning.) The scores of these 2 children were the same, both on that day and the previous day when they had received their sedation. It appears, then, that the perceptual acuity of these subjects does not seem to be affected by their hyperactivity. Rather, the deficiencies in learning may be due to their inability to apply sustained attention to a specific task without "overloading" or going beyond their own toleration point for processing sensory information.

The slight difference in scores between the average kindergarten and third grade samples suggests that children do gain in perceptual acuity as they grow older, and that the differences among the three tasks decrease when the subject has gained a certain level of maturity and experience. Hirsh and Sherrick (1961) report that the differences among the tasks are minimal in normal trained adults. Thus, one would expect an older group of children beyond the third grade to show even less differences in scores among the three specified modalities: visual, auditory, and the combined visual-auditory.

Within Group Task Correlations

In addition to an examination of between group comparisons on the specified tasks, it was also of concern in the present research to examine correlations between tasks as they occurred within each group. Table 9 shows a table of correlations of individual group performances between tasks.

TABLE 9

CORRELATION COEFFICIENTS
TABLE OF CORRELATIONS: INDIVIDUAL GROUP PERFORMANCE BETWEEN TASKS

Group	Column 1 Auditory v. Visual	Column 2 Auditory v. Combined Light/Tone	Column 3 Visual v. Combined Light/Tone
Average K (N=30)	.49**	.25	.38*
Slow-maturing K (N=32)	.13	.58**	.39*
Slow EH with auditory-language problems (N=22)	.14	.40*	.34*
Hyperactive EH (N=10)	.41	.13	.42
Average third grade (N=30)	.50**	-.10	.25*

*Differences significant from 0 at .05 level.

**Differences significant from 0 at .01 level.

Significantly different from zero:

N	.01 Level	.05 Level
10	.658	.497
22	.472	.344
30	.409	.296
35	.381	.275

Column 1, Table 9: Correlations between acuity in perceiving the first of two tones, and in perceiving the first of two lights

A close inspection of correlation coefficients for Column 1 suggests a consistent pattern delineating average from slow-maturing subjects. Low correlations between the auditory and visual task are apparent for the slow kindergarten and the slow EH groups. High correlations are shown for the average kindergarten and third grade. The comparatively small sample size (N=10) of the hyperactive EH group lessened the probability of showing significant data at any time.

Implications: The slow kindergarten and slow EH groups showed highly unequal task performance in the auditory and visual modalities. We know from Table 8 that the visual task is considerably quicker than the auditory. Therefore, for the two slow populations (K and EH with auditory-language problems) it can be deduced that (1) the correlation between auditory and visual acuity is extremely low--visual acuity is relatively keen, auditory is extremely deficient; (2) visual acuity must develop at an earlier age than does auditory acuity for normal children, even if they are slow-maturing; and (3) visual acuity is not adversely affected even when auditory acuity is so affected in brain-damaged children. A final deduction is the observation that (4) average performing groups at both kindergarten and third grade level are more equalized in their acuity of discerning the first of two events, whether the pairs of stimuli happen to be lights or pitch tones.

Column 2, Table 9: Correlations between auditory and combined light/tone tasks

It is noteworthy that the slow kindergarten (and to a lesser extent the slow EH) group showed a significant correlation between the auditory task and the combined light/tone task. On the other hand, such a correlation is either not significant or nonexistent for the two average groups.

Implications: Lack of sensory integration and poor auditory acuity are both attributes of immature development, and are apparent in the slow kindergarten group (and to a lesser extent in the slow EH group). The low-scoring kindergartners had trouble not only in classifying the first of two pitch tones; they also had deficits in the basic skill of using their ears and eyes in quick succession in indicating whether a tone or a light occurred first. A second deduction is that by third grade the average child has no difficulty whatsoever in designating whether the tone or light comes first; in this respect his intersensory discrimination is completely developed. If he should be slow in discriminating the first of two tones, it has nothing to do with his capability of designating the first of a pair in the light/tone task. Thus, a negative correlation between the combined light/tone task and the auditory task for the third grade.

<u>Column 3, Table 9: Correlations between visual acuity and the ability to discern a light or tone first in the combined task</u>

The correlations in this column do not differentiate average and slow-maturing populations as in the other columns. Thus, one can deduce that correlations here are not particularly meaningful or relevant in the present study.

In sum, correlation measures suggest specific areas of relationship for slow-maturing children, and other areas of relationship for average children. Average performing children of school age are more equalized in performance between the auditory and visual tasks, but not when the auditory task is compared to the cross-modal one. That is, if a deficit occasionally occurs in auditory processing, it does not occur in the cross-modal task as well for average children.

On the other hand, slow-maturing children are not equally adept at the visual and auditory tasks. Instead, they show a greater correlation in performance between the auditory and cross-modal tasks. Such data simply imply that slow maturation of the auditory processes is linked with slow development of the intersensory processes, but not with the visual processes.

All statistics reported in this study are based on the 100% correct response level, expressed in amount of time between stimulus onsets required for correct identification of the first of a pair of stimuli in every trial. The term <u>100% correct</u> refers to six correct answers out of six trials.

Summary

The statistical measures used in this section tested the proposed hypotheses, namely:

1. Slow-maturing kindergartners when compared to average kindergartners will be significantly deficient in the ability to order in quick succession pairs of lights, tones, or a tone and a light.

2. Educationally handicapped children with problems in auditory-language areas will be significantly deficient in the ability to order tones in quick succession when compared to a normal population of comparable age.

3. The auditory task will be more difficult than the visual for the two slow-maturing groups (kindergarten and educationally handicapped) but not for the average groups.

Results have suggested that these hypotheses are true, both in task-related and group-related comparisons. In reference to task-related comparisons, the ability to order in correct sequence two pitch tones was more difficult than a comparable ordering task with two lights for both the slow kindergartners and the EH subjects with auditory receptive problems. However, for average performing subjects, a significant correlation existed between the ability to do the pitch task and the light task, indicating that for these subjects there was no discrepancy in ability between the two tasks.

In reference to group-related comparisons, data reveal significant differences in the auditory task between the slow-maturing kindergarten group and the average kindergarten group; and again between the slow EH group and the average third grade. In addition, the cross-modal task seemed to be significantly more difficult for the two slow samples than for the average groups.

No appreciable differences existed between the average kindergarten and third grade, or between the hyperactive EH group without auditory-language deficits and the third grade.

Finally, correlation measures suggested that for average children acuity in the auditory and visual processing is comparable. For slow-maturing children, a different set of correlations existed. Slow maturation appears to be reflected in correlations between the auditory and the cross-modal tasks, but not between the auditory and visual tasks.

CHAPTER V

DISCUSSION

This research was stimulated by an interest in investigating the extent to which certain populations of children would respond to tasks requiring temporal ordering skills of lights, tones, or a combination of a light and a tone. Five populations were assessed, two at kindergarten level, and three in the category of 8-10 age range. For the kindergartners, slow-maturing were compared to average performing on the Metropolitan Readiness Tests. For the older children, an educationally handicapped sample with language processing deficits was compared to a hyperactive educationally handicapped group without language deficits, and to a normal third grade.

For the purposes of the present study the term "language processing" was loosely interpreted by considering in kindergartners their general readiness for reading, and for the educationally handicapped various auditory-language subtests. Since results indicated that significant differences did exist between the slow-maturing and average kindergarten populations, and also between one educationally handicapped and normal sample, it is appropriate to discuss now the extent to which the specified populations were deficient in "language processing skills."

The criterion measure for dividing slow kindergartners from average kindergartners was the Metropolitan Readiness Test. This test is not specifically a test of auditory-language skills. In fact, only three out of the six subtests relate directly to oral language at all. (A seventh subtest was also assessed in the present study, that is, the Goodenough "Draw-a-Man.") What was found from the results of the subtests of the Metropolitan Readiness Tests was a regular pattern of responses for the low kindergartners, and another pattern for the average kindergartners. That is to say, those who were slow on word concepts, listening skills, and number skills were also slow on copying skills, matching, and the "draw-a-man" exercise. On the other hand, among the average kindergartners, the majority of children reflected average scores on these subtests. Inspection of the raw data and the actual tests which the low-scoring kindergartners took reveal interesting parallels. Reversals cropped up in copying symbols: "b" for "g"; "z" for "s." Simple geometric forms could not be matched or copied at all. The children's concept of the human figure was either distorted or incomplete in their own drawings: arms coming out of the ears for one child; head and legs with no arms or body at all for another child. Finally, their concept of number relationships was completely undeveloped. In short, poor listening and verbal comprehension were only a portion of the result on the Metropolitan Readiness Score. The poor scores in language processing went hand-in-hand with poor scores in visual perception, motor control, and general cognitive development. Luria has hypothesized that the development of the speech processes in the brain is reflected not only in language, but also in perceptual processes (Luria, 1959). His assumption may account here for the similarities between verbal skills and visual-motor skills in the Metropolitan Readiness Tests. In addition, his assumption may account for the poor performance of the temporal ordering skills found in slow-maturing kindergartners in the present experiment.

One principal result of this study demonstrated that the low scores of the EH sample on the auditory subtests (auditory association, digit span, and grammatical closure) of the ITPA correlated with deficiencies in the temporal sequencing of pairs of tones. For the 22 EH children who failed the specified ITPA auditory subtests, it was shown that their mean score was significantly slower than the average third grade. On the other hand, the hyperactive EH subjects who were all within grade level on the specified ITPA subtests were also comparable with the normal third grade in perceptual acuity in the tone task. Such a difference between the two EH groups suggests that the auditory-language processing capability may indeed be a baseline of comparison when delineating differences in perceptual acuity in EH children of the 8-10 year age range.

For the normal children of third grade level, unfortunately, the specific ITPA subtests were not given. Only circumstantial evidence can be supplied here. We know that their scores for the pitch task were the quickest of the five groups tested. Reasons attributable for their fine scores in the present study may have been due to maturation and normal (as opposed to abnormal) cerebral functioning. "Normal cerebral functioning" would imply here for the most part more satisfactory scores on the auditory-language subtests of the ITPA than those received by the slow EH group, had the tests been given to the third grade.

In sum, the term "language processing" was loosely interpreted in the present study to include (1) an indication of kindergartners' general cognitive development and readiness for reading as measured by the Metropolitan Readiness Tests;

(2) scores on four specific auditory association and grammatical closure subtests in the ITPA for two samples of older educationally handicapped subjects; and (3) differences between normal third graders and those placed in educationally handicapped classes. As such, these criteria provided a basis for measuring five populations of children in the present study in temporal ordering skills. Results gave limited evidence that these criteria were adequate in delineating differences in temporal ordering skills in the following populations: slow-maturing from average kindergartners; EH with auditory-language deficits from hyperactive EH children and normal third graders.

Comparison of Slow Kindergartners with the Slow EH Group

The present research concerns differences between slow-maturing and average subjects at the crucial period before first grade; and differences between educationally handicapped and normal subjects in the 8-10 year age range. Now the question concerns the extent to which the pathological behavior found in the slow EH sample is also characteristic of the normal behavior of the immature sample of slow kindergartners. Statistical data suggest (1) that for the pitch task, at least, their mean scores are similar; and (2) that those who are immature in auditory skills also appear to be immature in the cross-modal task involving the perception of both the auditory and visual stimulus modalities. However, differences, as well as similarities, are apparent between the two slow groups. A larger proportion of the slow kindergarten group could not order the pitch tones at all, even though they could match one tone bell at a time. With the majority of children in the slow EH group, the problem was in separating the two tones far enough in time so that they could perceive the first of the pair. This was also true of approximately half of the slow kindergarten sample. With the rest of the slow kindergarten sample (44%) the problem was the inability to place in correct serial order the two pitch tones no matter how slowly the tones were given. In other words, almost half of the slow kindergartners were deficient in making sense out of the relationship of successive stimuli even when the two tones were struck at intervals of more than a second. Yet all but three of the children could identify the two separate tones, one by one.

A second point of difference between the two slow groups was in the visual task. The slow EH children were not significantly deficient in the visual task when compared to the normal third graders; whereas the slow kindergartners showed a significant difference when compared to the average kindergarten group.

Such results suggest on the one hand an uneven development of the cerebral processes for the slow EH group with language deficits, and on the other hand a generally low perceptual and cognitive development for the slow kindergarten sample.

Task Analysis of the Nature of the Deficits of the Slow Performing Groups

In order to analyze stages of the child's comprehension a task analysis was made of the level of his concept development in relation to the requirements of the present study. (This task analysis was presented earlier in the manuscript on page 13.) Even though some of the slow performing kindergartners and EH subjects were unable to order the stimuli in the pitch task and in the combined light/tone task, every child in the experiment could comprehend at least two basic prerequisites for the task. That is, it was established beforehand that every child understood the concept of same and different in reference to the sounds, and also of first and second (if not to the sounds themselves, at least to the order of the performance of the tone bells).

For the concept of same and different, E gently pressed the child's finger on one telegraph key in response to a specific tone. If the next pitch was the same, E and the child pressed that particular telegraph key; if different, they pressed the other telegraph key. When a conditioning effect was established, the child himself pressed with one hand one telegraph key for a tone, and with the other hand the other key for the opposing tone. Even the handful of slow children who were unable to match separate tones with their mallet somehow managed part of the time to perform this telegraph key test, even though their concentration may have lasted for only as little as six or eight separate response pressures before confusion set in on stereotyped alternations of the two response keys, with no coding going on for the sounds.

It should be qualified that the concept of same and different for each tone, one at a time, is a lower-level conceptual task when compared to that of designating how the first stimulus differed from the second in the criterion ordering task using pairs of stimuli. Yet it is a prerequisite to perceive at least that a difference is or is not occurring as successive stimuli are presented to the child. Only three children were excluded from the experiment because they did not perceive that a difference was apparent between the two bells. These children could all distinguish "same" or "different," however, when a percussive sound and a pitch tone were compared, and could perceive pairs of these sounds quickly and accurately. The possibility of real tone deafness was too great for these three youngsters, thus they were deleted from the experiment.

For the concept of "first" and "second," each child had to show the examiner that he could voluntarily play the bells in either order before he was tested on the ordering task. He also had to push appropriate buttons to make either a red or green light flash first and, finally, to make a light occur before a sound, or vice versa. Unfortunately, many slow kindergartners (and to a lesser extent, slow EH subjects) could voluntarily order the two pitch tones as required, yet were unable to detect the ordering pattern when someone else provided the stimulus. In short, they understood the concept but lacked the discrimination for pairs of events.

One way of showing E that the subject could recognize the order of a pitch pattern was to reproduce the pattern himself on his two tone bells. Another way was the criterion task used for this experiment of simply pointing to a bell which represented the first sound of an ordered pair. It was fascinating to observe the slow EH children who could actually reproduce the tone sequence correctly by striking the tone bells but who were unable to point to the first of an ordered pair when the rate of presentation was as slow as 600 msec.

This was an important observation. That is to say, it appeared that 6 out of 8 EH children scoring slower than 600 msec. in the tone task were apparently able to perceive the correct sequence at 600 msec. if the response was one of <u>playing</u> the pair in correct order rather than <u>pointing</u> to the first of the ordered pair. In other words their perceptual learning was guided by motor movement (almost automatic in nature) rather than by intellectual analysis. On the other hand, this phenomenon did not occur with slow-maturing kindergartners. Those who failed to point to the correct tone bell representing the first of an ordered pair also failed in reproducing correctly with their own mallet and tone bells a pattern of two tones.

In sum, the task analysis of each slow-performing child showed that four preliminary subtests on pitch were easier than the criterion task of designating the first of an ordered pair. These four tasks in hierarchical order of difficulty were: (1) demonstration by the child that he understood the concept of "first" and "second" by conscious manipulation of the tone bells himself in one or another designated order (in other words, the subject provided the stimulus himself); (2) the matching of separate tones as S's response to E's stimulus; (3) the encoding of the separate tones by means of pressure on one telegraph key or another; (4) the active response of S to pairs of tones by reproducing the pitch sounds in the correct order.

Every child in the experiment could perform the first task correctly, as described above. Practically every child could perform either task 2 of task 3 correctly to a limited extent (this means six out of six correct; average performing children could do 30 out of 30 correct without flagging). All but two of the slow EH children could perform task 4, as described above. As for the criterion tone task of ordering pairs of pitch tones by pointing to the first tone bell of a successive pair, only 27% of the slow EH children and 31% of the slow kindergartners could perform this task satisfactorily (under 600 msec. for the time interval between the tones). No matter how elemental a task the ordering of pitch tones seems to be, it required analytic ability combined with auditory discrimination. When the interval between the tones became shorter and shorter, perceptual analysis was too difficult for the majority of children with slow-maturing cognitive or language-processing skills.

General Concluding Remarks

The present experiment showed that a relationship exists between cognitive development and perceptual acuity in kindergarten. Unfortunately, many slow kindergartners are not ready to learn to read because of their undeveloped cognitive and perceptual processes which hinder them in grasping the meaning of successive events or of encoding them. In the present experiment, such deficiencies were especially apparent with the pitch tones and also with the combined light and tone, but not with the lights.

In some respects deficiencies in temporal ordering skills are similar for slow kindergartners and for slow EH children (8-10 years of age). However, the older child, even though educationally handicapped, has a sensory and muscular system of greater maturity. Therefore, the present experiment showed that slow EH children with language-processing deficits had an uneven development of the cognitive, motor, and perceptual processes, whereas the pattern of development for the slow kindergartners was consistently low.

The use of a temporal ordering instrument in the schools as a means of measuring the perceptual acuity in kindergartners and in educationally handicapped may be extremely beneficial and expedient for diagnostic measures. In addition, the technique and methodology developed for the present study would seem to offer especially possibilities for training purposes, particularly among slow-performing populations. Such an instrument might be one way of developing certain attentional habits, as well as skills in perceiving and encoding successive events in the immature or educationally handicapped child. As the instrument for measure exists at the present time, it is a fine diagnostic tool to supplement existing verbal and nonverbal tests. However, it is too early to spell out its potential or future value. If more complete assessment is made of younger ages, from a developmental standpoint (that is, under the 5-year age level), the present instrument will have even greater meaning and value as a diagnostic tool, and would clarify age-related changes in learning processes in children.

In the school district where this experiment was made, 27% of the kindergartners scored below the 40th percentile on the Metropolitan Readiness Tests, and an additional 28% scored between the 50th and 40th percentile. This total figure is large: 55% of a total population below the 50th percentile, categorized as "slow-maturing" in the present set of perceptual tasks. The proportion of slow-maturing kindergartners from a middle-class segment of the population has not been investigated. Nor do we have any real indication from the present study of the cause for such slow maturation processes among certain kindergartners. All that we really know is that differences do indeed exist, and that these differences correlate with reading readiness, and with slow perceptual encoding for successive events. Future research may be able to uncover other evidence pertaining to slow perceptual and cognitive development in young children which would give insight into the underlying biological reasons for a delay in their development.

On evaluating differences between the normal third grade and the two educationally handicapped groups, existing data have provided a baseline for comparison for future studies along these lines. Differences between one EH group (with language-processing deficits) and a normal sample are significant. Differences between the second EH group and a normal sample are minimal. This evidence in itself should lead to further investigations of how indeed the hyperactive EH and the normal child do differ in a number of perceptual and cognitive tasks, if not in temporal ordering skills, as shown in the present study.

The next step is remediation. If a novel method of diagnosing perceptual and cognitive deficiencies in young children has been found, now a method should be devised to facilitate their quickness and accuracy of perception of successive events. For example, the tests in the present study may in the future be used as a baseline for measuring effects of verbal training on acuity of perception of non-verbal events.

Summary

This research investigated temporal ordering acuity in children, or their ability to perceive the first of an ordered pair of lights, of tones, or of a combined light and tone, when the interstimulus time interval within each pair became increasingly short in duration. The basic assumption of the study was that the rapidity with which the child could perform such a skill would be a reflection of how effectively his perceptual and cognitive processes function when comprehending more complex stimuli. Two group-related problems were investigated: (1) differences between slow-maturing and average kindergartners, and (2) differences between a slow educationally handicapped group with language-processing difficulties and two other samples, a normal third grade and a hyperactive EH group without language-processing deficiencies. In addition, task-wise correlations measured relationships of task performance within groups.

Results indicated significant findings between the two younger populations in all three tasks, and between the slow EH group and normal third grade in the auditory and cross-modal tasks. Within-group correlations showed that (1) poor auditory processing and inadequate intersensory functioning go hand-in-hand for the slow-maturing kindergartners and the slow EH group; (2) visual acuity is not necessarily affected by deficiencies in the auditory or cross-modal areas, and (3) auditory and visual acuity are similar in the two normal groups and in the hyperactive group without language-processing deficiencies.

As a result of task performance in the present study, the term "slow-maturing" for normal kindergartners is now qualified to imply a generally low perceptual and cognitive development, whereas for the older EH group with language-processing deficiencies, the term "slow" now implies a more localized unevenness in perceptual and cognitive functioning. Among normal third graders without significant reading problems, the present tests do not delineate differences in mental age.

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APPENDIX

TEMPORAL ORDERING AND SERIAL ORDERING SKILLS IN RETARDED READERS

Data on the experiment just discussed show interesting gradations of ability among the children within the 8-10-year age range, that is, among normal third graders, educationally handicapped subjects with language-processing difficulties, and hyperactive EH subjects. What was not investigated was the ordering ability of <u>significantly retarded readers</u>.

An opportunity presented itself near the completion of the experimental period to test a group of 12 children considered to be significantly retarded in reading. Although they attended the regular classroom (either the second or third grade), they received additional individual instruction in reading by language specialists in a reading clinic each day for an hour. It was not ascertained whether these children were significantly retarded in reading because of educational and language deprivation in the home, contributing to slow maturing of their cognitive processes, or because they indeed had a minor neurological dysfunction. It should be clarified here that none of these children qualified for the educationally handicapped classes such as the two samples described earlier in this report. In other words, they had no pathological symptoms other than extreme reading retardation and generally poor performance in school. The following quotation by Rabinovitch (1968, p. 4) may clarify the distinction made between this group of 12 children and those EH subjects tested earlier in this report.

> Basically, there are two groups of reading retardations: (1) those in which the reading retardation reflects a definitive neurological dysfunction in the absence of history or signs of brain injury (referred to as primary reading retardation, or developmental dyslexia), and (2) those in which the reading retardation is not primary but is secondary, or reactive, to other pathology or problem.

Rabinovitch qualifies further where the problem lies for children with primary reading retardation: namely, the inability to deal with letters and words as symbols, thereby diminishing their ability to integrate the meaningfulness of written material.

Rationale

The rationale for testing retarded readers was to discover (1) whether they were significantly slow on temporal ordering skills; (2) what kinds of errors such children make in serial ordering skills, for example, reversals of order, perseveration, superfluous digits, omissions, or simple inaccuracies of one member of a given pair; and (3) whether children of this particular sample reflected specific and consistent patterns of errors in their serial ordering skills among the auditory, visual and tactile modalities.

Description of a Serial Ordering Task

The serial ordering tasks of this experiment required the child to spell out longer patterns perceived in three sense modalities: visual, auditory, and tactile. The visual patterns consisted of the red and green lights; the auditory of high and low tone bells. In addition, a new stimulus modality was introduced, namely, that of electro-vibratory pressure on the skin of the abdomen as one more receptor channel to the brain. The task using the imput on the skin consisted of deciphering and recalling short patterns of successive vertical and horizontal lines, applied by electro-vibratory pressure midway on the skin of the abdomen.

Definitions

Temporal ordering was still considered to be the ability to order pairs of stimuli in the minimum time level possible for each subject.

Serial ordering was now considered as the ability to reproduce longer patterns of three or four members in the correct order. The time element was no longer a factor, since all stimuli were presented at a constant (one-second) inter-stimulus interval.

Related Research

Use of the Skin as a Receptor Modality

Comparatively little research exists showing the effectiveness of learning by means of the skin. Yet recent studies have demonstrated the feasibility of using the skin of the body as a substitute sensory channel to transmit pictorial information to the brain. By using a recently invented portable tactile-visual substitution system, Bach-y-Rita, Scadden, and their associates have shown that cutaneous vibratory stimuli delivered to the skin of the back or abdomen can relay information to the brain (Bach-y-Rita et al, 1969; Scadden, 1971). Although such a system has been successfully used in limited clinical experiments for adult blind subjects, its possibilities have not been explored for children who have deficiencies in reading. Previous studies using the tactile-visual substitution system have shown that subjects perceive a quality of depth perception and spatial arrangement of objects (Bach-y-Rita, 1969; Scadden, 1971). However, practically no investigation has been made of how children recall and reproduce in correct serial order patterns applied to the skin.

One study has been made which suggested that the skin might be an effective receptor for receiving and encoding symbols, especially for children who normally reverse them when they are seen. Jampolsky (1969) found that tactile stimuli on the back helped children who normally reverse numbers to write them correctly. By conditioning techniques the investigator aimed to train dyslexic children to write the numbers "1" to "10" without reversing the symbols. His equipment included an electro-vibratory unit which produced vibrations on the subject's back. After one month's training, including kinesthetic arm movements, the children in the experimental group made significant improvement in their ability to write numbers without reversals.

Dyslexia

Reading retardation can be due to a number of different kinds of reading deficiencies in children and in adults (Rabinovitch, 1968). The problem of reversals in directionality and symbol order, usually defined as "dyslexia," is only one aspect of reading retardation. In the present experiment every child selected was known to reverse letter order and the directionality of symbols in his reading, as well as to have difficulty in comprehending the meaning of words.

Procedure

Population

The sample included 12 subjects (4 girls, 8 boys) who were either repeating the second grade or were in the third grade in school. They had been screened by learning specialists and teachers as having significant deficits in reading. Standardized reading tests (Coop Reading; Stanford-Binet) showed each child to be at least a year below his own grade level in reading ability. Mean age was 105 months.

For the temporal ordering task, the control group was the average third graders of the preceding experiment. For the serial ordering tasks, no control group was used for the tactile task, since it was given so late in the experimental period. However, between-group comparisons were obtained for the auditory and visual aspects of the serial ordering task. That is, 12 subjects were randomly selected from the normal third grade and assessed in their ability to reproduce patterns of lights or patterns of tones. Because of the omission of a control sample for the tactile task, this appended research can be considered only as a descriptive pilot study, suggesting future areas of research in serial ordering skills among children.

Testing Procedure

The testing procedure for the acuity of perceiving the first of an ordered pair has been described earlier in this report.

For the serial ordering task with the lights, tones, and tactile electro-vibratory pressure on the child's skin of the abdomen, the stimulus signals, paced at one-second intervals, were consistently the same in duration and interstimulus intervals. The order of presentation of the light task, the tone task, and the tactile pressure varied from subject to subject. Testing was done on two consecutive days for each subject.

Patterns Used

A set of 10 patterns was given three times, once with the lights, once with the pitch tones, and once with the tactile pressure. For example, if the pattern was given in the visual modality, it might be red-green-red-red. The same pattern in the auditory modality (pitch tone) would be low-high-low-low. For the tactile modality, the pattern on the skin would be

| — | |. It should be qualified that these vertical and horizontal lines, presented successively, appeared on the same central area of the child's skin of the abdomen: one line after the other, in temporal order; that is, these lines were not distributed in a spatial arrangement.

TABLE 10

PATTERNS USED IN THE SERIAL ORDERING TASK

Modalities: visual (lights); auditory (tones); tactile (vertical and horizontal lines)

Pattern	Distribution	Pattern	Distribution
1	+ + −	6	+ − − +
2	− − +	7	− + + −
3	− + −	8	+ + − +
4	+ − +	9	− − + −
5	− + +	10	+ − + +

Method of Response

For the light task, the child took from E's hand a small response box on which were two buttons. Around one button was colored a red circle; around the other, a green circle. The child simply pressed the appropriate buttons in correct order to obtain the desired sequence of light signals in response to the pattern he had just seen.

For the tone task, the child reproduced the order of each pattern by playing the tone bells placed in front of him. This procedure was described in detail earlier in this report.

For interpretation of the vertical and horizontal lines felt on his skin, the child traced with his finger either the top of a vertically arranged plastic cylinder, or along the top of a horizontal one. That is, he used only these two objects, and would retrace his finger, if necessary, when successive lines occurred in the identical direction. The tactile part of the test was given only after the child had practiced with E for an extra session, eyes shut, in identifying separate lines on the skin.

Instrumentation of Testing

For the visual and auditory stimuli, the same equipment was used as for the experiment of perceived order of auditory and visual stimuli. However, now the lights or tones came slowly, one by one, instead of in pairs. For the tactile stimuli on the child's abdomen, Dr. Matti Nurmia, who had constructed the auditory and visual mechanism, also devised a lightweight harness to be attached to the child. Members of the Institute of Visual Sciences were consulted. Within the harness there were electro-vibratory signals which were either vertical or horizontal in direction on the child's skin. These impulses were timed from the same stimulus generator used for the lights and tones.

Kinds of Errors and Scoring

Children were assessed on several kinds of errors: reversal of order of symbols ("R"); inclusion of superfluous components within a pattern ("S"); omission of one member of a pattern ("O"); and inaccuracies in one member of a pattern ("IN"). Another kind of error recorded was that of perseveration ("P"). For the purposes of this study, the term "perseveration" implies an inability to shift from one pattern to another. For some children, it is sometimes difficult to erase the image of one pattern in the mind's eye and to answer correctly for the next pattern. They seem to be "stuck in their tracks," or persist in repeating one pattern even though another pattern is now to be reproduced.

In Table 10, it is obvious that every other pattern seems to be followed by another which is exactly the reverse order of its "+" and "-" symbols. This was planned to detect how children could shift from one ordering to a completely opposite ordering without perseverating.

The number and kinds of errors that each child made on each of the serial ordering tasks were itemized. Comparisons were made among the three tasks.

The <u>temporal acuity tasks</u> were scored as previously described in this report, that is, six responses out of six stimulus pairs had to be correct at a given interval rate. T tests were made to compare the significance of differences in each temporal ordering skill between the retarded readers and the average third grade.

Results

This appended pilot study was an attempt to measure temporal ordering skills and serial ordering skills in a new sample of children of the 8-10 age range, namely, significantly retarded readers.

Temporal Ordering Skills

The following are the mean scores of the significantly retarded readers (N=12) in temporal ordering skills. A T test comparing the mean scores of this group with the average third grade showed that significant differences existed between the two groups in the auditory and the combined auditory/visual task. No significant differences were apparent in the visual task.

TABLE 11

MEAN SCORES IN MILLISECONDS SHOWING ACUITY OF PERCEPTION IN DISCRIMINATING THE FIRST MEMBER OF A PAIR OF STIMULI FOR RETARDED READERS (AGES 8-10) AND AVERAGE THIRD GRADERS

	Lights	Tones	Combined Light/Tone
Retarded readers (N=12)	124.00	658.18*	355.83
Average third grade (N=30)	86.3	219.33	200.00

T-ratio for tone task = 4.5407; df = 39; sig. level = .01
T-ratio for combined tone/light task = 3.3268; df = 40; sig. level = .01

*One member of the retarded readers was unable to order the pairs of tones. Thus the sample for this task is N=11.

Serial Ordering Task

Table 12 shows that all 12 members of the retarded reading group made errors in one or more of the modalities for the serial ordering task.

TABLE 12

RETARDED READERS FAILING SERIAL ORDERING TASK
(N=12)

	No. of Subjects	Per Cent
Failed at least 2 patterns in each modality (auditory, visual, tactile)	5	42
Failed at least 2 patterns in auditory and tactile modalities	3	25
Failed at least 2 patterns in auditory modality alone	3	25
Failed at least 2 patterns in tactile modality alone	1	8

The results shown in Table 12 indicate that almost half of the subjects made errors in all three sensory modalities, that two-thirds made errors in the auditory and tactile modalities, but not in the visual. Only one child was deficient in the tactile modality and not in the others. It is noteworthy that no child made errors <u>only</u> in the visual serial ordering task, but not in the other modalities. No child in this group got a perfect score.

The average third grade sample was tested only on the auditory and visual serial ordering task, but not on the tactile. A random selection of 12 subjects from this group yielded 8 out of 12 <u>absolutely perfect scores</u>. Although no statistical comparisons were made, it is obvious that significant difference in accuracy of serial ordering of auditory and visual stimuli exists between average third graders and significantly retarded readers (that is, 67% perfect scores for a whole set of patterns for average third graders versus no perfect scores for retarded readers). Whether such a difference exists also in the tactile task remains for future research to discover.

Kinds of Errors Made in Serial Ordering Tasks

Average third graders. For the average third grade control population only four subjects made errors. Two of these subjects each made three errors in perseveration ("P"). Two subjects omitted part of one pattern in their response ("O"). All of these errors occurred in both the auditory and visual modalities for these four subjects.

Retarded readers. In Table 13, results suggest that reversal of order is by far the most common kind of error in serial ordering for retarded readers, and that the reversals occur more frequently with auditory and tactile stimuli than for visual. One other kind of error seemed to occur frequently for retarded readers, that is, the response which indicates superfluous digits. For example, a response for "+ - + +" might be "+ - - + +" or "+ - + + +" in order to be considered "superfluous." It seems that the impression of a whole pattern is "fuzzy" with retarded readers, and inaccurate in length of pattern as well as in its order, thus errors in "superfluity" of response and in reversals.

TABLE 13

KINDS OF ERRORS MADE IN THE SERIAL ORDERING TASK BY RETARDED READERS

Modality	R	O	P	IN	S	Total
Auditory						
No. of errors	19	4	6	7	11	47
No. of subjects making errors	6 (50%)	3 (25%)	3 (25%)	3 (25%)	7 (58%)	
Visual						
No. of errors	4	6	7	2	10	29
No. of subjects making errors	4 (33%)	3 (25%)	2 (16%)	2 (16%)	4 (33%)	
Tactile						
No. of errors	27	5	3	1	7	43
No. of subjects making errors	7 (58%)	2 (16%)	1 (8%)	1 (8%)	2 (16%)	
Total Errors	50	15	16	10	28	

Code: R = reversals of whole or part of pattern; O = omission of part of pattern; P = perseveration; IN = inaccuracy of one member of pattern; S = superfluous extension of pattern by repetition of one member.

A further inspection of reversal errors among the three tasks for the retarded readers yielded the following data.

TABLE 14

REVERSAL ERRORS IN AUDITORY, VISUAL AND TACTILE MODALITIES BY RETARDED READERS

	Modality		
No. of Subjects	Auditory	Visual	Tactile
3	X	X	X
1	X		X
3			X
1		X	
2	X		
Total	6	4	7

This table does not yield a consistent pattern of reversal behavior throughout the modalities. While 33% made reversal errors in the auditory and tactile modalities, another 50% made reversal errors in only one modality and not another. Finally, 17% of the retarded readers did not make reversal errors at all; nevertheless this 17% of the subjects did make other kinds of errors in the serial ordering task.

Conclusions

Retarded readers, when compared to average third graders, were (1) significantly slower in temporal ordering of pairs of stimuli, and (2) considerably less accurate in serial ordering of whole patterns of stimuli. Such differences appeared in the auditory and cross-modal tasks for the temporal ordering test; and in the auditory and visual tasks for the serial ordering test. Unfortunately no between-group comparisons are available for the tactile task in serial ordering.

These results involve a small sample population of retarded readers. From this limited sample size it appears that an underlying correlation exists between temporal ordering acuity and serial ordering skills in retarded readers. Whether or not such a correlation exists among other populations deficient in school learning should be investigated in further research.

In all tasks, the ordering of the two lights, red and green, seemed easier for retarded readers than did the ordering of two tones. Future investigations should substitute different kinds of visual symbols for the lights; for example, a "T" versus an "X"; or a "U" versus an "N" might lend more insight into how these children order visual forms used in reading.

In the serial ordering task the kind of errors found most frequently among the retarded readers was that of reversing the order of a pattern. Yet the results are puzzling. Consistent behavior of reversing patterns in <u>all</u> the modalities was not found. In the present experiment such errors were most apparent in the auditory and tactile modalities, but not so much in the visual. Yet it is with visual stimuli that these children make reversal errors in reading and writing meaningful verbal material in their daily school work.

As the experiment stands, all that we know is that reversing the order of symbols is the most common error among significantly retarded readers. If successive auditory or cross-modal events occur at too great a speed, such children confuse their order. If these events occur at a slower speed but with a longer pattern length, reversals still occur in the serial order. Thus, it appears that speed of presentation, length of pattern, and the nature of the stimulus are all factors which contribute to reversals of symbol order in retarded readers' serial ordering tasks.

Future Implications Using Tactile Imput

It is not known from the present experiment how effective the tactile modality would be for retarded readers as a reinforcing agent for perceiving the spatial arrangement and temporal ordering of symbols correctly. Possibly a systematic study may show that motor activity of the hand and arm in making imaginary letters as they are perceived on the skin would indeed reinforce the visual image of symbols (cf. Jampolsky, 1969). It may also be found that imput on the skin would establish new intersensory connections in retarded readers which would help them in general learning skills pertaining to spelling and reading. These areas will have to be explored more thoroughly in future research.

Summary

This appended research tested differences between retarded readers and average third graders in temporal ordering of pairs of stimuli in the auditory, visual, and combined auditory-visual modalities. In addition, it assessed differences in "digit" memory or serial ordering of longer patterns consisting of two tones or two lights or a vertical and horizontal line interpreted on the skin.

For the temporal ordering tasks, significant differences appeared between the retarded readers and the average third grade in the tone task and the combined light/tone task. These results are indeed similar to those of the educationally handicapped sample with language-processing problems in the previous experiment.

For between-group comparisons of the serial ordering task, differences were clear-cut between average and retarded readers: 67% of the average population had absolutely perfect scores on ordering patterns in the auditory and visual modalities, whereas no child among the retarded readers achieved a perfect score on any one set of patterns. No differences between populations were measured for the tactile task.

Within-group comparisons on serial ordering skills indicate that over 50% of retarded readers reverse the order of symbols in at least one of the three specified modalities (auditory, visual, or tactile). No reversals occurred in pattern ordering for the average population. Further investigation is recommended in reference to reversals in serial ordering and its relation to speed of temporal ordering for all children with learning problems.

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