DETERMINANTS OF AUDITORY-VISUAL INTEGRATION
IN ELEMENTARY SCHOOL CHILDREN

By

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required standard

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September, 1970
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ABSTRACT

Chairman: Professor Robin N. Smith.


This study was designed to examine a number of factors which might affect the ability to equate auditory and visual non-verbal stimuli as measured by performance on the auditory-visual integration (AVI) test of Birch & Belmont (1964, 1965) and Kahn & Birch (1968). In this test S is presented with an auditory dot pattern and is required to identify the one of three printed visual dot patterns which is the same as the one heard. Short-term auditory memory, stimulus length and sex differences were studied as possible factors affecting performance on the AVI test.

A random selection, from three elementary schools, of 108 third-grade children, 54 males and 54 females, were assigned to one of two groups. Two modified forms of the AVI test defined as the consecutive presentation and the simultaneous presentation, were administered, one to each group of Ss. The first of these tests presented the auditory and visual stimuli consecutively;
that is, the auditory stimulus, after a delay of 5 sec.,
was followed by three visual stimuli presented one at a
time, of which one corresponded to the auditory stimulus.
It was proposed that this presentation format would involve
short-term auditory memory as a possible factor affecting
the judgments of auditory-visual equivalence. The second
test presented the auditory and visual stimuli simultaneously
as pairs; that is, there was no delay between the auditory
and visual stimuli. Each of three visual stimuli was presented
simultaneously with the same auditory stimulus. It was
assumed that this presentation would eliminate short-term
auditory memory as a factor affecting auditory-visual integration
competence.

It was found that third-grade children were able to process
the simultaneous presentation of auditory and visual non-verbal
stimuli, at certain stimulus lengths, with more facility than
they were when the same stimuli were presented in the consecutive
mode. This result supported the hypothesis that there might be
a significant short-term auditory memory factor in performance
of the AVI test and that this memory component might be signific­
antly related to judgments of auditory-visual equivalence.

The position of the visual stimuli was also found to affect
the recognition of auditory and visual pairs in the AVI test.
The effect, significant though small, occurred for both the
consecutive and simultaneous presentations, indicating that interference or decay of sensory processing did occur whether the presentation was consecutive or simultaneous for stimuli in the third position. It was suggested that interference and/or decay in short-term memory, might account for the impaired ability to make correct judgments of auditory-visual equivalence for stimuli in position three as compared to stimuli in positions one and two for the consecutive presentation. The assumption of proactive interference was invoked to account for the occurrence of the same phenomenon in the simultaneous presentation.

Another finding indicated that stimulus length per se might not be a significant factor affecting the difficulty of auditory-visual equivalence judgments, but that a factor related to length might be. The results are consistent with a theory of recoding input stimuli and suggest that an increase in the number of units of stimuli to be retained and not the number of stimuli per unit, might be the factor affecting the difficulty level of auditory-visual equivalence judgments.

Sex of the children was not found to affect performance on the AVI tests significantly.

Further research considerations in the area of AVI were advanced.
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The current emphasis in education on reading problems and individual learning differences of children has led to the emergence of the area of "learning disabilities." A number of approaches to the study of this area are being investigated. This introduction deals with one of these approaches, the process of sensory integration.

Numerous tests have been developed and studied which measure the integration of various combinations of sense modalities. One of the most extensively examined tests is the auditory-visual integration test developed by Birch and Belmont (1964, 1965) and expanded by Kahn and Birch (1968). This test has been found to be significantly related to a number of aspects of reading acquisition and not to be significantly influenced by visual and auditory discrimination, verbal mediation or auditory memory.

The purpose of this study was to examine a number of factors which may influence AVI. The variables of short-term auditory memory, stimulus length and sex differences have been selected for study. Specific hypotheses are presented and rationalized in Chapter III.
Auditory-Visual Integration (AVI) and Reading

Judd (1927) states:

"Oral language is the natural basis upon which the reading of beginners must be developed... recognition of printed words depends upon the analysis of visual sensory materials ... these units must at first be made to coincide with their oral counterparts."

Buswell (1947) adds:

"The reading process is basically a kind of perceptual learning in which visual symbols are perceived and related to already known auditory symbols of spoken language."

Learning to read as an educational task requires the ability to transform spatially distributed visual patterns into temporally distributed auditory ones. Harris (1948) has suggested that for the beginning reader "reading is largely concerned with learning to recognize the symbols which represent spoken words." A primary disturbance in the ability to integrate stimuli from the 2 critical sense modalities, hearing and vision, may well serve to increase the risk of becoming a poor reader. Consequently, one of the characteristics underlying reading readiness as well as some types of reading retardation may be the development of the ability to make judgments of auditory-visual equivalence. These judgments require the translation from a visual stimulus to the auditory equivalent.

One of the first studies concerned with the process of AVI was carried out by Birch & Belmont (1965). They concluded
that by the time a child has reached the eighth year of life he must be able to use information gained from both auditory and visual stimuli. Their study explored intermodal integration: i.e., the child's ability to equate intersensory (auditory and visual) information. It was found that the capacity to make such equivalence judgments was significantly correlated with reading test scores in first and second grades, and thus suggested that this competence may be crucial for the acquisition of reading skills.
Chapter II

Survey of the Literature - Theory and Research

Theory

Auditory-Visual Integration (AVI)

Vision and hearing differ from each other in a number of ways, one of which is that vision gives us a great deal of information about precisely how things are laid out from left to right, up and down, etc., that is, how things are arranged in space. Hearing, on the other hand, gives us only a crude picture of spatial arrangements, but is organized instead as a sequence of events strung out in time. Therefore, when we talk about AVI we are usually also referring to temporal-spatial integration which is the ability to integrate information that is arranged as a string of events in time with information given as an arrangement in space. A number of people (e.g., Judd, 1927; Buswell, 1947; Edfeldt, 1960) have pointed out that when the child reaches school age, he has previously acquired an auditory language, defined as the ability to understand and produce speech. The first step in learning to read is for the child to recognize that a new language-code, the printed page, is equivalent to the already familiar auditory one. His
task then involves learning to "translate" from speech-language into and out of the new language code of printed words. The speech-language code is an auditory one and is arranged purely as a sequence in time, while the printed page is not auditory and has no time organization. Thus in learning to read, the child must be able to make translations between auditory and visual information as well as between temporal and spatial organizations. A deficit or developmental lag in either of these translation abilities would seem to place severe limitations on the ability to learn to read (Sterritt, Martin & Rudnick, 1968).

Research

The Development of the Auditory-Visual Integration (AVI) Test

The study of AVI was initially applied to children and the educational process by Birch and his co-workers (Birch, 1962; Birch & Belmont, 1964, 1965). In order to examine children's ability to translate between auditory and visual information Birch & Belmont developed the AVI test which explored the relationship between a temporally structured set of auditory stimuli and a spatially distributed set of visual ones. The task was the identification of a visual dot pattern that corresponded to the patterning of a rhythmic auditory stimulus. The
auditory dot pattern was tapped once with a pencil, followed by the exposure of three visual dot patterns presented together, one of which was the same as the auditory stimulus.

The studies of Birch & Belmont have shown significant relationships between children's performance on the AVI test and reading ability and intelligence. The analysis suggests that the ability to treat visual and auditory patterned information as equivalent is one of the factors that differentiate good from poor readers. Auditory-visual pattern test performance did differentiate subjects with lower than those with higher reading scores in their groups of normal and retarded readers. However, their 1965 results were attenuated at older age levels due to a lack of sufficient ceiling in their measure of AVI and they reported no reliability data for their ten-item test.

In an unpublished study of boys in Grades 2 through 6, Kahn (1965) remedied these deficiencies by adding ten items to the test and by obtaining test-retest reliability data (published in 1968 by Kahn & Birch). Test-retest reliability results, obtained approximately 10 days apart, yielded reliability coefficients of .76 for the third grade group and .90 for the fifth grade group. Ford (1967) reported the test-retest reliability for 30 grade four boys tested 7 days apart, as .60.
Birch & Belmont's study was extended by Beery (1967) with more precise control of intelligence. She examined the matching of auditory equivalents to a visual standard. Her findings were consistent with those of Birch & Belmont; retarded readers were significantly deficient in recognizing the equivalence of stimuli presented in succession to two modalities, the effect being present whether the visual or auditory stimulus was the standard.

Muehl & Kremenak (1966) were concerned with the ability to match information within and between auditory and visual sense modalities, and subsequent reading achievement. They used tasks requiring visual-visual, visual-auditory, auditory-visual and auditory-auditory matching. Their results indicate that when used as predictors, only scores made under visual-auditory and auditory-visual input conditions made significant contributions to predicting reading success.

Factors Associated with AVI

Several researchers have examined the AVI test in an attempt to define possible mechanisms involved in AVI competence which may also be found in the reading process and thus influence the relationship between AVI and reading.

1. Intelligence

Ford (1967) reported a positive relationship to exist between
intellectual ability and both reading achievement and AVI scores, as have Birch & Belmont (1964, 1965), Sterritt & Rudnick (1966) and Kahn & Birch (1968). These studies reported that measures of reading and intelligence share a large common variance. Ford computed partial correlations which indicated that whatever the AVI test has in common with reading is also in large part what it has in common with intelligence so that when intelligence is held constant the relationships are reduced to near zero. Because of the close relation generally found between measures of intelligence and reading achievement, as usually measured, Ford concludes that these partial correlations have relatively little meaning.

The results of Ford's study differ from those of Kahn & Birch (1968) and Sterritt & Rudnick (1966) who reported that intelligence does not account for all the variance. Partialing for either Verbal or Nonverbal I.Q. did not eliminate the significant association between AVI scores and reading achievement.

2. **Auditory rhythm and visual pattern discrimination**

Kahn & Birch (1968) found insignificant auditory rhythm and visual pattern discrimination differences between children scoring highest and lowest on the AVI test. They concluded that the relative ease of the discrimination task suggested that
the degree of visual and auditory discrimination skill required for accurate performance on the test was well within the range of all subjects in the sample.

3. Short-term auditory memory

Ford (1967) correlated the AVI scores of thirty subjects at the grade four level with their scores on the Digit Span subtest of the Wechsler Intelligence Scale for Children in order to determine to what extent auditory memory was related to performance on the AVI test. The Pearsonian $r$ between the two tests was found to be .03 indicating that auditory memory skills are not specifically associated with AVI test performance at the grade four level. These results are consistent with those of Kahn & Birch (1968) but contrast to those of Rodenborn & Brown (1970) and Sterritt, Martin & Rudnick (1968) who found auditory memory to be a significant factor in the AVI test. The former authors reported that 16.3 per cent of the variance of AVI was accounted for by auditory memory. These results suggest that there may be a memory factor inherent in the design of the AVI test which may not be identified by the use of the Digit Span subtest.

4. Methods of approaching AVI

Ford analyzed AVI test performance in terms of two aspects:
(1) position choices and (2) methods used to solve the task. She found the making of systematic position choices was associated with poor performance on the task and that the majority of subjects used a counting procedure in solving the task. The other Ss used body movements primarily to do the task, usually by tapping fingers. Some used both methods. Reliance on body movements alone to solve the task was found predominantly in Ss scoring below the mean on the test.

Kahn & Birch (1968) also noted differences in methods used by their Ss on the AVI test. They categorized the methods as counting, visualization, feeling and unknown. The results show the percentage of Ss able to express their method of approach increased with age, with counting procedures forming the largest group of reported methods at all grade levels. The findings do not suggest that the ability to apply verbal labels to the auditory and visual stimuli affected AVI test performance in a positive manner or that a specific method was related to I.Q. Rather, inspection of the results indicate that the children who used counting procedures, a method which applied verbal labels to the test stimuli, showed the lowest AVI mean scores at each age. Moreover, the group which stated that they tried to visualize the auditory patterns directly, an approach with little, if any, verbal mediation implied in its execution, tended to show higher AVI mean scores than the counting group at all grade levels.
(This is not surprising since the visualization group implies the forming of the visual equivalent to the auditory pattern and this, it is suspected, would facilitate the auditory-visual equivalence judgement). Thus, although conclusions based on data using verbal reports about methods should be treated with caution (Birch & Rabinowitz, 1951; Maier, 1932), these findings of Kahn & Birch do not suggest that either the attempt by the child to apply verbal labels to the auditory and visual stimuli or the general capacity of verbalizing a method of approach were important influences on AVI competence in the sample tested. Although Blank & Bridger (1966) have suggested that the ability to apply verbal labels to the auditory and visual stimuli is a pertinent variable in mediating cross-modal competence, the evidence of the study does not support this position (Kahn & Birch, 1968).
CHAPTER III

EXAMINATION OF THE AVI TEST AND PROBLEM

Components of the AVI Test

Examination of the AVI test suggests a number of variables, as well as those identified by Kahn & Birch (1968) and Ford (1967), which may influence performance on this test. These variables are listed below:

1. Auditory
   a) Rhythm discrimination
   b) Short-term auditory memory

2. Visual
   a) Pattern discrimination
   b) Scanning - 1. within each stimulus; 2. across stimuli.

3. Cross-modal Interference
   a) Within each stimulus
   b) Across stimuli

   a) Yes or No written response
Auditory Rhythm and Visual Pattern Discrimination

The results of Kahn & Birch (1968) suggest that these factors are not related to AVI competence.

Visual Scanning

In a recent paper concerned with ocular motility (eye movements) and reading Goldberg (1970) concludes that it is likely that the degree of comprehension produces the type of ocular movement and not ocular motility that determines the degree of comprehension. That is, it has been assumed that learning difficulties in some cases were due to lack of binocular coordination and in-coordinate eye movements were noted in children who had difficulty in reading. Goldberg has shown that eye movement may be to a considerable degree dependent upon the conceptual difficulty of the reading material. This does not discount the possibility that a child affected by in-coordinate eye movements may have difficulty reading but does limit it to very specific cases.

Due to the simplicity of the visual patterns in the AVI test, the findings of Goldberg suggest the effects of visual scanning may be minimal in AVI performance.

Assuming that auditory and visual pattern discrimination as well as visual scanning have negligible effect, the AVI
test has the following components:

1. **Auditory**
   a) Short-term auditory memory

2. **Cross-modal Interference**
   a) Within each stimulus
   b) Across stimuli

3. **Auditory-Visual Equivalence Judgment**
   a) Yes or no written response

**Short-Term Auditory Memory**

Although both Kahn & Birch (1968) and Ford (1967) have found insignificant correlations between the AVI test performance and the Digit Span subtest of the Wechsler Intelligence Scale for Children, auditory memory would appear on a priori grounds to be an important variable inherent in the design of the test. The consecutive presentation (in which the auditory pattern is followed after a delay by the 3 visual patterns) requires the retention of the auditory pattern in order to equate the auditory and visual stimuli. Also since the dot patterns progressively increase in length, auditory retention is involved in order to retain these longer sequences of dots. It would appear reasonable to assume that if any
portion of the auditory stimulus is "forgotten" before the equivalent visual stimulus is selected the correct judgement will not be made. This assumption is congruent with the statements on auditory memory by Senf (1969). Senf notes that it would appear fruitful to consider immediate memory as playing a significant role in learning to read. Clearly, sufficient immediate memory capacity is necessary so that the beginning of a word or sentence is not forgotten by the time the end of the word or sentence is read (Senf, 1969). This would appear to apply to judgments of AVI and the tests designed to measure this ability.

Further examination of the Digit Span subtest of the Wechsler Intelligence Scale for Children indicates that it may measure different aspects of auditory memory than those found in the AVI test. Although Digit Span appears similar to the AVI test in that it requires retention of increasing lengths of material, it differs in that it employs verbal material (numbers) in contrast to the AVI test's non-verbal material (dots). It has been previously suggested by Belmont, Birch & Belmont (1968), Kimura (1961, 1964) and Mountcastle (1962) that verbal and non-verbal tasks are not equivalent. Digit Span also requires an input (auditory) and output (verbal recall) modality combination which the AVI test does not. The above points taken together with the results of Sterritt, Martin &
Rudnick (1968) and Rodenborn & Brown (1970), who reported a significant memory effect for their sequence-perception tests, raise enough questions to suggest that further study of the role of short-term memory in performance of the AVI test is required.

**Cross-Modal Interference and Stimulus Length**

The possible effects of cross-modal interference have not been examined. During the retention period from the onset of the auditory stimulus to the final processing and recognition of the equivalent visual stimulus, the processing of intervening visual stimuli may interfere with the retention of the previously presented auditory stimulus. Since cross-modal interference is involved in the memory processes of the auditory stimulus, its effect may be confounded with those of short-term auditory memory. This effect may increase as stimulus length increases and the number of stimuli encountered prior to each visual stimulus increases. Fewer errors may result when the visual stimulus is the first encountered, with no intervening stimuli, than when it is the second or third, with one and two intervening stimuli, respectively. Possibly stimulus length may also increase the frequency of errors due to the required retention of longer auditory patterns, increased time to process visual patterns and the resulting increased total retention period.
The process of cross-modal interference is one of the interference effects of poststimulus events referred to by Aaronson (1968). Sperling (1963) has found that post-exposure fields of "visual noise" (made of jumbled pieces of letters) "erased" the initial visual stimulus information from memory. Interpolated events occurring within about one sec., after the initial stimulus presentation caused large decrements in recall accuracy, but decrements decreased and leveled off with further increases in the interpolated delay (Brown, 1955). Brown concludes that interpolated events occurring immediately after the presentation may interfere with the perception of the stimuli, while later interpolated events would interfere only with rehearsal. Aaronson states that perceptual processes continue to occur after the physical stimulus presentation -- either auditory or visual -- is terminated. Interference with or termination of these postpresentation perceptual processes can lead to decreased recall accuracy in short-term memory tasks, whether the interference is inter- or intra-modal.

Considerations Arising from Previous Research

The use of heterogeneous samples of children from grades two through six by Kahn & Birch (1968) and of grade four boys by Ford (1967), may have obscured significant relationships of auditory memory at different levels of reading achievement.
A pilot study carried out by the writer with grade one and grade four subjects, grouped according to below-average and above-average reading achievement, suggests that auditory memory may be a significant factor with the below-average group only. This effect, if occurring in the above studies, would tend to be obscured by the heterogeneous nature of the samples employed by Kahn and Birch (1968) and Ford (1967).

Most previous studies of AVI have not examined sex differences (e.g., Birch & Belmont, 1965; Sterritt, Martin & Rudnick, 1968) or have limited their samples to male subjects to eliminate sex differences commonly found in reading achievement and thus thought to also affect performance on the AVI test (Rudnick, Sterritt & Flax, 1967; Ford, 1967). Hurley (1968) and Rodenborn & Brown (1970), using intersensory integration tests, have found no indication of sex-based differences contrary to the above assumptions. Further evidence is required in this matter.

A number of studies concerned with AVI and employing the AVI test can be questioned in regard to the research methods used. Sterritt & Rudnick (1966) pointed out that in the original studies of Birch & Belmont the auditory patterns were tapped out with a pencil on the edge of a table. No mention was made of any screen or other arrangement to prevent S from seeing the tapping pencil and S apparently received visual as well as
auditory cues in the auditory pattern representation. They conclude that it is not clear to what degree Birch & Belmont's test may reflect the ability to transpose from temporal to spatial formats within the visual modality rather than the ability to transpose between audition and vision. Kahn & Birch as well as Ford can also be questioned on procedure. Both studies state that the auditory patterns were tapped out by hand; Kahn & Birch behind a cardboard screen and Ford under a table on a metal plate. There is no mention of the number of examiners involved, and the possible variance in the auditory pattern presentations due to within examiner differences from pattern to pattern and subject to subject or between examiner differences, although Ford states that there was a \( \frac{1}{2} \) -second pause between short intervals and a 1-second pause between long intervals in the auditory stimulus. The delay between the cessation of the auditory stimulus and the presentation of the visual stimulus is also not noted and may result in varying retention periods. The lack of standardized presentation procedures may produce confounding effects on the results of several of the studies on auditory-visual integration.

**The Problem**

The purpose of this study was to determine whether short-term auditory memory, stimulus length & sex differences affect
children's ability to equate auditory and visual non-verbal stimuli.

Short-term auditory memory was selected due to the inconsistent findings of previous research. Stimulus length and sex differences were included due to the lack of research on their relation to AVI. A number of other factors which might have confounded interpretation of the results were introduced to allow study of these variables and any interactions they might have.

It was suggested that if a test of AVI which included the factors of short-term auditory memory and cross-modal interference and their possible interactions with stimulus length was administered to a group of children and a second test of AVI which excluded or reduced these factors was administered to a similar group of children, the former group of children would score at a lower level to the degree that these factors and their interactions affected AVI.

It was hypothesized that AVI might be inhibited by the presence of:

(1) Short-term auditory memory

(2) Increasing stimulus length

(3) Interference effects of positions of visual stimuli (confounded within short-term auditory memory)
(4) Positions of visual stimuli and short-term auditory memory interacting with
stimulus length, and

(5) Sex differences.

Research hypotheses based on the experimental design
are stated in Chapter IV.
CHAPTER IV

METHOD

Subjects

The sample consisted of 108 third-grade elementary school children from the West Vancouver School District, West Vancouver, B.C. Each child was randomly selected from a population of males and females from one of three elementary schools and assigned to one of 18 groups of Ss each consisting of three males and three females. Each group of Ss was then randomly assigned to a group position from one to 18. The group position determined the treatment condition that it would receive. No child was included in the study who evidenced any uncorrected auditory or visual defect, as determined by the school screening tests.

AVI Test Description

In order to study the effects of short-term auditory memory, and stimulus length as they relate to the task of auditory-visual integration, two modified forms of the auditory-visual integration test (Birch & Belmont, 1964, 1965) were presented to these subjects. For both presentations the task for each S was to equate an auditory-temporal dot pattern with a visual-spatial dot pattern.
The S was required to determine whether or not each of three visual dot patterns was equivalent to the pattern of the auditory stimulus.

**Presentation A₁ (consecutive)**

Each auditory stimulus, presented via a tape recorder, was repeated three times with an interval of 3-sec. between repetitions. The third repetition was followed by a delay of five seconds before exposure, one at a time, of the three visual dot patterns. Each visual dot pattern was displayed for a period of time equivalent to the time taken for one repetition of the auditory stimulus. There was a 3-sec. delay between visual stimuli. Immediately preceding onset of the auditory stimulus, a verbal signal "ready" was given and between each auditory repetition a verbal signal "again" was given. During the five seconds between the cessation of the auditory repetitions and the onset of the visual stimuli was a verbal signal "Now you will see the dots, ready." The three visual dot sequences were cued by "number one", "number two" and "number three" in that order.

An illustration of one auditory stimulus and its three visual dot patterns as well as the presentation format follows:

<table>
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<th>Visual</th>
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<tr>
<td>&quot;Ready&quot;</td>
<td>&quot;Now you will see the dots&quot;</td>
</tr>
<tr>
<td>&quot;Again&quot;</td>
<td>&quot;No. 1&quot;</td>
</tr>
<tr>
<td>&quot;Again&quot;</td>
<td>&quot;No. 2&quot;</td>
</tr>
<tr>
<td>&quot;Again&quot;</td>
<td>&quot;No. 3&quot;</td>
</tr>
<tr>
<td>3-sec</td>
<td>5-sec</td>
</tr>
<tr>
<td>3-sec</td>
<td>3-sec</td>
</tr>
<tr>
<td>3-sec</td>
<td>3-sec</td>
</tr>
</tbody>
</table>
Presentation A₂ (simultaneous)

This form also presented three repetitions of the auditory pattern together with the three visual patterns in succession, and three repetitions of the auditory pattern, but each of the visual stimuli occurred simultaneously with one of the auditory repetitions. That is, the three visual patterns from which the specific selection was to be made were presented in conjunction with the same auditory pattern. Each auditory and visual stimulus combination was repeated once with an interval of 3-sec between repetitions. Each visual dot pattern was displayed simultaneously with the onset of the auditory stimulus and terminated with the cessation of the auditory stimulus. Immediately preceding onset of each auditory and visual pair, a verbal signal "ready" was given. Each of the auditory and visual pairs was cued by "number one", "number two", and "number three" in that order.

An illustration of one auditory stimulus paired with its three visual stimuli as well as the presentation format follows:-

<table>
<thead>
<tr>
<th>&quot;Ready&quot;</th>
<th>&quot;No. 1&quot;</th>
<th>&quot;No. 2&quot;</th>
<th>&quot;No. 3&quot;</th>
<th>Auditory</th>
</tr>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3-sec</td>
</tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Visual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3-sec</td>
</tr>
</tbody>
</table>
Examination of the two methods of presentation shows that $A_1$ includes the factors of auditory memory and stimulus length. The auditory memory factor is involved since there is a delay between the cessation of the auditory stimulus and the exposure of the visual stimuli. Due to the fact that the visual stimuli are displayed successively there is a greater delay between the cessation of the auditory stimulus and the exposure of the visual stimulus in the third position than the visual stimulus in the first position. Auditory memory is also involved in the retention of longer auditory patterns and it was thought that this increasing stimulus length might interact with position effect.

As mentioned previously (Chapter III) intervening visual stimuli might interfere with the retention of the auditory stimulus and Presentation $A_1$ includes the possibility of this post-stimulus interference. This effect is confounded with the short-term auditory memory effect for presentation $A_1$.

Presentation $A_2$ reduced auditory memory as a factor due to the simultaneous presentation of the auditory and visual stimuli. Stimulus length will remain as a factor only within an auditory stimulus and can no longer interact with the position of the correct visual stimulus.

Due to a number of variables involved in the AVI test of Birch & Belmont that might confound interpretation, other fac-
tors were introduced into the design of the two presentations to exercise some measure of control of possible order effects and to allow study of these variables and any interactions they might have.

At each stimulus length there were three different visual dot patterns. Three visual items at each length were selected in order to allow each of the three positions to be represented once as a correct choice. The position of the correct visual stimulus was varied systematically at each length. This allowed study of any influence the position of response in the multiple-choice sequence of three positions might have. The order of item presentation was also systematically varied across groups of Ss. The "system" employed was one that gave no advantage to any group of Ss in regard to the order of item presentation, or presentation of the correct response within the items (refer to Figures 3 and 4).

Test Materials

The auditory patterns were presented via a Sony TC-900 S tape recorder in order to standardize presentation and to eliminate intra-examiner differences. The auditory tone was generated by a Buchla attack generator through a touch-control voltage source to an oscillator. The sound from the oscillator was given attack and decay characteristics resulting in a sine
wave of 700 cycles/sec recorded on a Hewlett Packard Electronic Counter, Model 3734A. The durations of the "short" and "long" pauses between the auditory stimuli of a given pattern were 1/2-sec and 1-sec., respectively.

Each of the three visual stimuli was presented on a separate 2 x 3 inch white index card. The lengths of the "short" and "long" spaces between the visual stimuli of a given pattern were 5/16-in. and 5/8-in., center to center of two adjacent dots, respectively. Each dot had a diameter of 1/4-in.

One set of 18 auditory stimuli and the 54 visual stimuli from which selections were made is shown in Figure 1. The format and stimuli varied across groups of Ss but Figure 1 illustrates all the types of auditory and visual stimuli used. Six stimulus lengths, four dots/pattern to nine dots/pattern, were included in the present study as were included by Birch & Belmont (1964) and Kahn & Birch (1968).

Test Format

The Ss were tested in groups of six for both presentations. The groups of Ss were tested in a random order which resulted in the order of the administration of A₁ or A₂ also being random. In order to increase the number of observations of AVI, the study was replicated over groups at an interval of approxi-
### Auditory Tap Patterns

<table>
<thead>
<tr>
<th>Test Items</th>
<th>L₁</th>
<th>L₂</th>
<th>L₃</th>
<th>L₄</th>
<th>L₅</th>
<th>L₆</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>:..</td>
<td>:..</td>
<td>:..</td>
<td>:..</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>:..</td>
<td>:..</td>
<td>:..</td>
<td>:..</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>:..</td>
<td>:..</td>
<td>:..</td>
<td>:..</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Visual Stimuli

<table>
<thead>
<tr>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
</tbody>
</table>

---

Figure 1. Auditory-visual dot patterns for Group 1 (A₁₀₁)**

* L - Stimulus length

** A₁ - Presentation; 0₁ - order
mately 24 hours. The replication followed the same random order of administration of $A_1$ and $A_2$.

**Test Situation**

Each group of $S$s, 3 males and 3 females, were seated in a semi-circle around a projection screen (Figure 2). Behind the $S$s was an opaque projector and tape recorder. Each $S$ was given a score sheet numbered 1-18 which also included practice items a, b and c.

![Figure 2](image)

**Figure 2**

**Testing Situation**

$S$ = subject; $E$ = examiner
The auditory tap patterns were presented via the tape recorder. The visual dot patterns were presented by the projector on the projection screen located in front of the Ss. E controlled the tape-recorder and also was responsible for coordinating the presentation of the visual patterns.

Experimental Design

The study was analyzed by a 2 x 3 x 3 x 2 x 6 x 3 repeated measures factorial design replicated twice with Latin Square arrangement for two order effects. The between Ss variables under study were method of presentation (A₁, A₂), order of stimuli (0₁, 0₂, 0₃), groups of Ss at each presentation and order combination (G₁ - G₁₈) and sex of Ss. The within Ss variables were length of stimuli (L₁ - L₆) and position of correct visual stimulus (P₁, P₂, P₃). Method of presentation, order of stimuli, sex, length of stimuli and position of correct visual stimulus were fixed factors. The subject factor was random.

The dependent variable was the number of correct AVI judgments for each S under the different position-by-length combinations, over the two replications. Each S could obtain a score ranging from zero to six by making six AVI judgments for each position at each length. The possible range of scores for each replication was zero to three.
A schematic representation of the design is shown in Figures 3 and 4.

The basic design (Figure 3) included the two methods of presentation, the six stimulus lengths, the three positions of the visual stimuli and the three orders of item presentation. Each position was represented an equal number of times at each stimulus length. Three orders of item presentation were employed to counterbalance individual stimulus item difficulty over positions within each length. This was done by the Latin Square method. Each item was also represented an equal number of times at each position.

Each item was composed of three different visual stimuli. Each of these visual stimuli occupied either stimulus position one, two or three within an item. Figure 4 indicates the method in which individual stimuli within each item were represented an equal number of times across Ss at each position. This arrangement was used as a method of controlling individual stimulus difficulty within each item.

Groups of Ss (G1 - G18) nested within presentation-by-order (AX0) are introduced in Figure 4 as well as the sex factor (M,F). It will be noted that groups reflect differences in the constitution of the groups, differences in the level of difficulty within items and differences in the level of difficulty between stimuli within items.
<table>
<thead>
<tr>
<th>L₁</th>
<th>L₂</th>
<th>L₃</th>
<th>L₄ - L₆</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P₁</td>
<td>P₂</td>
<td>P₃</td>
</tr>
<tr>
<td>O₁</td>
<td>I₁</td>
<td>I₂</td>
<td>I₃</td>
</tr>
<tr>
<td>A₁</td>
<td>I₃</td>
<td>I₁</td>
<td>I₂</td>
</tr>
<tr>
<td>O₃</td>
<td>I₂</td>
<td>I₃</td>
<td>I₁</td>
</tr>
<tr>
<td>A₂</td>
<td>repeat</td>
<td>repeat</td>
<td>repeat</td>
</tr>
</tbody>
</table>

I = item (3 visual stimuli)
L = length of stimuli (dots/pattern)
P = position of correct visual stimulus
O = order of items
A = method of presentation

**Figure 3**

Design: Latin Square of position and items at each length for A₁. This design is repeated for L₄ - L₆ and for A₂.
<table>
<thead>
<tr>
<th></th>
<th>L₁</th>
<th></th>
<th>L₂</th>
<th></th>
<th>L₃</th>
<th></th>
<th>L₄-L₆</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P₁</td>
<td>P₂</td>
<td>P₃</td>
<td>P₁</td>
<td>P₂</td>
<td>P₁</td>
<td>repeat</td>
</tr>
<tr>
<td>G₁</td>
<td>MF</td>
<td>ABC</td>
<td>DEF</td>
<td>GHI</td>
<td>ABC</td>
<td>DEF</td>
<td>GHI</td>
</tr>
<tr>
<td>G₂</td>
<td>MF</td>
<td>CAB</td>
<td>FDE</td>
<td>IGH</td>
<td>CAB</td>
<td>FDE</td>
<td>IGH</td>
</tr>
<tr>
<td>G₃</td>
<td>MF</td>
<td>BCA</td>
<td>EFD</td>
<td>HIG</td>
<td>BCA</td>
<td>EFD</td>
<td>HIG</td>
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<tr>
<td>G₄</td>
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<td>MF</td>
<td>HIG</td>
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<tr>
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<td>MF</td>
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<td>GHI</td>
<td>ABC</td>
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<td>ABC</td>
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<td>G₈</td>
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<td>FDE</td>
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<td>FDE</td>
<td>IGH</td>
<td>CAB</td>
</tr>
<tr>
<td>G₉</td>
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<td>HIG</td>
<td>BCA</td>
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<tr>
<td>G₁₀</td>
<td>repeat</td>
<td>repeat</td>
<td>repeat</td>
<td>repeat</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ABC - order of visual stimuli within item 1 (L₁); correct visual stimulus underlined for length 1 (L₁).

BCA - order of visual stimuli within item 1 (L₁); correct visual stimulus underlined for length 1 (L₁).

Design: Order of presentation of the visual stimuli within each item for each group of Ss in A₁ from L₁-L₃. This design is repeated from L₄-L₆ and for A₂.

Figure 4

-33-
Figure 4 also illustrates the order of presentation of the visual stimuli within each item (I) for each group of Ss (G) at each stimulus length (L) and the position of the correct visual stimulus (P) within each item at each length. It will be noted that for $A_1O_1$ ($O_1$ refers to the order of items, not order of stimuli within items) $G_1$ is presented the three visual stimuli (A, B, C) comprising $I_1$ in the order ABC while $G_2$ receives the order CAB and $G_3$ the order BCA. Position of the correct visual stimulus remains constant at $P_1$ which results in the correct visual stimulus being A, C and B for $G_1$, $G_2$ and $G_3$ of $A_1O_1$ respectively. $G_1$ is then presented the three visual stimuli (D, E, F) comprising $I_2$ in the order DEF while $G_2$ receives the order FDE and $G_3$ the order FED. Position of the correct visual stimulus changes to $P_2$ which results in the correct visual stimulus being E, D and F for $G_1$, $G_2$ and $G_3$ of $A_1O_1$ respectively. This system is repeated for $G_1$, $G_2$ and $G_3$ with the visual stimuli G, H and I. The position of the correct visual stimulus changes to $P_3$. This procedure of counterbalancing the order of items and the order of the three visual stimuli within each item at each length is duplicated for all groups of Ss.

**Hypotheses**

The research hypotheses set out in Chapter III are cast as follows:
There will be significant differences in AVI scores as a function of:

(1) Presentations ($A_2 > A_1$)
(2) Stimulus lengths ($L_1 > L_2 > L_3 > L_4 > L_5 > L_6$)
(3) Positions of stimuli ($P_1 > P_2 > P_3$)
(4) Positions x stimulus lengths ($P \times L$)
(5) Positions x presentations ($P \times A$)

A further hypothesis is cast as a "null" hypothesis:
There will be no significant difference in AVI scores as a function of:

(6) Sex (males vs. females)

Statistical Treatment

The data consisted of the number of correct AVI judgments made by each $S$ under the different position-by-length combinations over the two replications. Each response to an auditory and visual pair of stimuli was treated as an independent AVI judgment. The total number of AVI judgments was 54 per replication with three AVI judgments being made for each position and length combination.

To test the hypotheses, the data were analyzed using the Bio-Med 08V analysis of variance program, revised January 30,
1969 at the Health Sciences Computing Facility, U.C.L.A. A one-tailed F-test was employed for hypothesis (1); hypotheses (2) and (3) were analyzed by the Newman-Keuls (Winer P.309) procedure for examining differences among pairs of ordered means; and two-tailed F-tests for hypotheses (4), (5) and (6). Also in order to avoid assumptions about equal covariances in the pooled variance-covariance matrices, a more conservative test, Greenhouse & Geisser (1959) & Box (1954), was applied to the significant main and interactional effects. Though not an exact test, this provides a lower bound on tabled probabilities for given α-levels.
CHAPTER V

RESULTS

Table I presents the complete summary of the analysis of variance of the between $S$s and within $S$s variables.

Hypothesis (1) $(A_2 > A_1)$ was not confirmed by the data. $(F(1,72) = 2.26; p > .10)$. The mean AVI scores for presentation $A_1$ (consecutive) and $A_2$ (simultaneous) were 5.18 and 5.39, respectively. These results indicate that there was no significant difference in AVI scores between the simultaneous and consecutive presentations, when averaged over the levels of the other factors.

Hypothesis (2) $(L_1 > L_2 \ldots L_6)$ was also not confirmed by the data. $(F(5,360) < 1.0)$. Significant differences in AVI scores were not found among stimulus lengths. This result held when means were for the combined $A_1$ and $A_2$ presentations.

$H_0$ for hypothesis (3) $(P_1 > P_2 > P_3)$ was rejected. $(F(2,144) = 5.48; p < .005)$. This position effect remained statistically significant with application of the Greenhouse and Geisser F-test. $(F(1,72) = 5.48; p < .025)$. The mean AVI scores for $P_1$, $P_2$ and $P_3$, illustrated in Figure 5, were 5.33, 5.30 and 5.22, respectively. Individual comparisons with
TABLE I
SUMMARY OF THE ANALYSIS OF VARIANCE

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Prob.</th>
<th>Prob.* (G-G)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Ss (Subjects)</td>
<td>107</td>
<td>21.62</td>
<td>21.62</td>
<td>2.26</td>
<td>.83</td>
<td>.93</td>
</tr>
<tr>
<td>A (presentation)</td>
<td>1</td>
<td>21.62</td>
<td>21.62</td>
<td>2.26</td>
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<td>.93</td>
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<tr>
<td>O (order)</td>
<td>2</td>
<td>15.99</td>
<td>7.99</td>
<td>.83</td>
<td>.83</td>
<td>.85</td>
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<td>S (sex)</td>
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<td>13.67</td>
<td>13.67</td>
<td>1.43</td>
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<td>.43</td>
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<tr>
<td>G/A x O (groups)</td>
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<td>213.27</td>
<td>17.77</td>
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<td>.18</td>
<td>.18</td>
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<tr>
<td>A x O</td>
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<td>1.37</td>
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<td>L x G/A x O</td>
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<td>109.94</td>
<td>1.83</td>
<td>2.30</td>
<td>&lt;.01</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>L x S x O x A</td>
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<td>6.78</td>
<td>.68</td>
<td>.85</td>
<td>.85</td>
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</tr>
<tr>
<td>L x S x G/A x O</td>
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<td>47.40</td>
<td>.79</td>
<td>.99</td>
<td>.99</td>
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</tr>
<tr>
<td>L x Ss/S x G/A x O</td>
<td>360</td>
<td>287.36</td>
<td>.80</td>
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-38-
### TABLE I - continued

<table>
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<tr>
<th>Source of Variation</th>
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<th>MS</th>
<th>F</th>
<th>Prob.</th>
<th>Prob.* (G-G)</th>
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<tbody>
<tr>
<td>P (position)</td>
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<td>.06</td>
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<td>.94</td>
<td>3.42</td>
<td>&lt;.01</td>
<td>&lt;.05</td>
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<tr>
<td>P x O x A</td>
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<td>.14</td>
<td>3.5</td>
<td>&lt;.01</td>
<td></td>
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<td>1.59</td>
<td>&lt;.10</td>
<td></td>
</tr>
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<td>1.41</td>
<td>&lt;.025</td>
<td></td>
</tr>
<tr>
<td>P x G/A x O</td>
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<td>.42</td>
<td>1.09</td>
<td>&lt;.01</td>
<td></td>
</tr>
<tr>
<td>P x S x O x A</td>
<td>4</td>
<td>.38</td>
<td>.09</td>
<td>.25</td>
<td>&lt;.10</td>
<td></td>
</tr>
<tr>
<td>P x S x G/A x O</td>
<td>24</td>
<td>6.40</td>
<td>.27</td>
<td>.68</td>
<td>&lt;.05</td>
<td></td>
</tr>
<tr>
<td>P x Ss/S x G/A x O</td>
<td>144</td>
<td>56.04</td>
<td>.39</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L x P</td>
<td>10</td>
<td>2.37</td>
<td>.24</td>
<td>.70</td>
<td>&lt;.01</td>
<td>&gt;.05</td>
</tr>
<tr>
<td>L x P x A</td>
<td>10</td>
<td>1.19</td>
<td>.12</td>
<td>.35</td>
<td>&lt;.01</td>
<td></td>
</tr>
<tr>
<td>L x P x O</td>
<td>20</td>
<td>18.58</td>
<td>.93</td>
<td>2.76</td>
<td>&lt;.01</td>
<td></td>
</tr>
<tr>
<td>L x P x S</td>
<td>10</td>
<td>2.40</td>
<td>.24</td>
<td>.71</td>
<td>&lt;.01</td>
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</tr>
<tr>
<td>L x P x A x O</td>
<td>20</td>
<td>12.65</td>
<td>.63</td>
<td>1.88</td>
<td>&lt;.05</td>
<td>&gt;.10</td>
</tr>
<tr>
<td>L x P x S x A</td>
<td>10</td>
<td>1.13</td>
<td>.11</td>
<td>.34</td>
<td>&lt;.10</td>
<td></td>
</tr>
<tr>
<td>L x P x O x S</td>
<td>20</td>
<td>7.77</td>
<td>.39</td>
<td>1.15</td>
<td>&lt;.05</td>
<td>&gt;.10</td>
</tr>
<tr>
<td>L x P x G/A x O</td>
<td>120</td>
<td>63.26</td>
<td>.53</td>
<td>1.57</td>
<td>&lt;.01</td>
<td>&gt;.10</td>
</tr>
<tr>
<td>L x P x S x O x A</td>
<td>20</td>
<td>5.08</td>
<td>.25</td>
<td>.75</td>
<td>&lt;.05</td>
<td>&gt;.10</td>
</tr>
<tr>
<td>L x P x S x G/A x O</td>
<td>120</td>
<td>34.53</td>
<td>.29</td>
<td>.86</td>
<td>&lt;.01</td>
<td></td>
</tr>
<tr>
<td>L x P x Ss/S x G/A x O</td>
<td>720</td>
<td>242.23</td>
<td>.37</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* These are conservative probabilities as determined by Greenhouse & Geisser (1959).
Mean AVI scores for position

Figure 5
Newman-Keuls among the position-means indicate that the mean AVI scores for P_3 were significantly lower (p < .05) than those of P_1 and P_2, which did not differ significantly.

Hypotheses (4) (P x L) and (5) (P x A) were not confirmed by the data. No significant differences in AVI scores were found for positions as a function of stimulus length (F(10,720) < 1.0) or for positions as a function of presentation (F(2,144) < 1.0).

Hypothesis (6) (males vs. females) was not rejected by the data. (F(1,72) = 1.42; p > .10). These results indicate that there were no significant differences in AVI scores for males and females averaged over presentation methods and the other factors. The mean AVI scores were 5.37 and 5.18 for males and females, respectively.

The interactional effect of presentation x length (A x L) was significant. (F(5,360) = 7.05; p < .001). This effect remained significant with application of the Greenhouse & Geisser F-test. (F(1,72) = 7.05; p < .005). The mean AVI scores for this interaction are illustrated in Figure 6. Tests of simple effects between presentation-means (Table II) indicate that significant differences in AVI scores occurred between presentations A_1 and A_2 but only from stimulus lengths 3 to 5.

Tests of simple effects between length-means for presentation A_1 (Table III) indicate that there is a significant decrease
Figure 6. Mean presentation AVI scores as a function of length
TABLE II

TESTS OF SIMPLE EFFECTS BETWEEN PRESENTATION-MEANS WITHIN LEVELS OF L FOR THE A X L INTERACTION

<table>
<thead>
<tr>
<th></th>
<th>L_1</th>
<th>L_2</th>
<th>L_3</th>
<th>L_4</th>
<th>L_5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_1</td>
<td>.291</td>
<td>.569</td>
<td>6.15*</td>
<td>4.65*</td>
<td>6.72**</td>
</tr>
<tr>
<td>A_2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>L_6</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_1</td>
<td>2.26</td>
</tr>
<tr>
<td>A_2</td>
<td></td>
</tr>
</tbody>
</table>

MSe = .798   d.f. = 360
n = 54

Critical values: F(1,360) = 3.84; p < .05*
F(1,360) = 6.63; p < .01**
### TABLE III

**TESTS OF SIMPLE EFFECTS BETWEEN LENGTH-MEANS WITHIN LEVELS OF A1 FOR THE A x L INTERACTION**

<table>
<thead>
<tr>
<th></th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>L6</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>.01</td>
<td>4.38*</td>
<td>3.04</td>
<td>3.46</td>
<td>.76</td>
<td></td>
</tr>
<tr>
<td>L2</td>
<td>L3</td>
<td>L4</td>
<td>L5</td>
<td>L6</td>
<td>L3</td>
<td>L4</td>
</tr>
<tr>
<td>L1</td>
<td>4.88*</td>
<td>3.46</td>
<td>3.91*</td>
<td>.97</td>
<td>.12</td>
<td></td>
</tr>
<tr>
<td>L2</td>
<td>L3</td>
<td>L4</td>
<td>L5</td>
<td>L6</td>
<td>L3</td>
<td>L4</td>
</tr>
<tr>
<td>L3</td>
<td>.05</td>
<td>1.49</td>
<td>.01</td>
<td>.76</td>
<td>.98</td>
<td></td>
</tr>
</tbody>
</table>

MSe = .798  
d.f. = 360

n = 54

**critical values:**  
F (1,360) = 3.84; p < .05*  
F (1,360) = 6.63; p < .01**
in AVI scores at \(L_3\) and a non-significant increase at \(L_6\).

Table IV indicates the tests of simple effects between length-means for presentation \(A_2\) and the non-significant increase in AVI scores at \(L_3\).

Examination of the data shows that there were no significant differences attributable to the effect of order of stimulus items. \((F(2,72) < 1.0)\). Mean AVI scores for \(O_1\), \(O_2\) and \(O_3\) were 5.32, 5.16 and 5.37, respectively. Significance, however, was found for the three-way interactional effect of order \(x\) length \(x\) position \((O \times L \times P)\). \((F(20,720) = 2.76; p < .01)\). This effect did not remain statistically significant with application of the Greenhouse & Geisser F-test. \((F(2,72) = 2.76; p > .05)\). A type I error might well be made if \(O \times L \times P\) were regarded as significant.

The interactional effect of groups \(x\) length within presentation and order \((G \times L/A \times O)\) was significant. \((F(60,360) = 2.29; p < .01)\). This effect remained significant with application of the Greenhouse & Geisser F-test. \((F(12,72) = 2.29; p < .05)\). This interaction was found too complex to interpret in any reasonable way.

The interactional effect of groups \(x\) length \(x\) position within presentation and order \((G \times L \times P/A \times O)\) was significant \((F(120,720) = 1.56; p < .01)\) but did not remain significant with
TABLE IV

TESTS OF SIMPLE EFFECTS BETWEEN LENGTH-MEANS
WITHIN LEVELS OF A_2 FOR THE A x L INTERACTION

<table>
<thead>
<tr>
<th>F-values between pairs</th>
<th>L_1</th>
<th>L_2</th>
<th>L_3</th>
<th>L_4</th>
<th>L_5</th>
<th>L_6</th>
</tr>
</thead>
<tbody>
<tr>
<td>L_1 L_2</td>
<td>.01</td>
<td>1.08</td>
<td>1.32</td>
<td>1.77</td>
<td>1.77</td>
<td></td>
</tr>
<tr>
<td>L_1 L_3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L_1 L_4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L_1 L_5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L_1 L_6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L_2 L_3</td>
<td>1.00</td>
<td>1.23</td>
<td>1.67</td>
<td>1.67</td>
<td>.01</td>
<td></td>
</tr>
<tr>
<td>L_2 L_4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L_2 L_5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L_2 L_6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L_3 L_5</td>
<td>.08</td>
<td>.08</td>
<td>.03</td>
<td>.03</td>
<td>.00</td>
<td></td>
</tr>
<tr>
<td>L_3 L_6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L_4 L_5</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L_4 L_6</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>L_5 L_6</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

MSe = .798  d.f. = 360
n = 54

critical values: F (1,360) = 3.84; p < .05*
  F (1,360) = 6.63; p < .01**
the Greenhouse & Geisser F-test. \((F(12,72) = 1.56; p > .10)\).  
Presentation x order x length x position \((A \times O \times L \times P)\) 
was also significant. \((F(20,720) = 1.88; p < .05)\). This effect 
also did not remain significant with the Greenhouse & Geisser 
F-test. \((F(2,72) = 1.88; p > .10)\).
CHAPTER VI

DISCUSSION

Stimulus Length and Miller's Theory of "Chunking"

Third-grade children's ability to process auditory and visual non-verbal stimuli presented consecutively decreased significantly when the stimulus length increased from 5 dots/pattern (length 2) to 6 dots/pattern (length 3). This is suggested by the breakdown of the AXL interaction. A fixed-effects analogue of the components of variance approach estimates the "variance component" $\sigma_{AL}^2$ to be .0298. This figure is 8.9 per cent of the value estimated for experimental error ($\sigma^2 = .3364$). The effect, though significant, is of small magnitude, and it is hazardous to attempt theoretical explanations of such small effects. But in so far as they are reliable, though small, the following suggestions seem consistent with the data.

According to Miller's (1956) theory of chunking, immediate memory appears to be limited by the number of items to be retained, regardless of the information content of the items. Because of this, Miller found that the apparent memory span could be increased by a recoding process. In order to speak more
precisely, therefore, we must recognize the importance of grouping or organizing the input sequence into units or chunks. Since the memory span is a fixed number of chunks for each set of conditions, we can increase the number of bits of information that it contains simply by building larger and larger chunks, each chunk containing more information than before.

Miller uses an example of a man who, just beginning to learn radio-telegraphic code, hears each dit and dah as a separate chunk. Soon he is able to organize these sounds into letters as chunks, then words and phrases. Input is given a code that contains many chunks with few bits per chunk. The operator recodes the input into another code that contains fewer chunks with more bits per chunk. There are many ways to do this recoding but probably the simplest is to group the input events, apply a new name to the group and then remember the new name rather than the original input events. Investigation of the "methods" used by children would perhaps help to explain this phenomenon.

An application of the "chunking" theory to the present study appears quite reasonable. If each dot can be conceptualized as a bit of information, examination of the dot patterns reveals that the stimulus of 4 dots/pattern (length 1) and that of 5 dots/pattern (length 2) are composed of 4 and 5 bits each,
respectively. Each stimulus pattern can then also be separated into chunks since the physical presentation of the dots presents the patterns with some dots separated by one-half a second and others by one second. The stimuli both auditory and visual, therefore, are presented as groups of dots separated by one second intervals or longer spaces. The dot pattern ... which is composed of 4 bits is also divided into 2 chunks, 2 bits/chunk. This also applies to ... which is 5 bits in 2 chunks, 3 and 2 bits/chunk. All the stimuli from length 1 to length 2 are separated into 2 chunks. At length 3 (6 bits) the patterns are divided into 3 chunks each. This is true of all stimuli from length 3 to 9 dots/pattern (length 6).

The increase in errors from length 2 to length 3 for the consecutive presentation may not be the result of the increase in the number of dots/length since there is no corresponding increase in errors as the number of dots increases from length 3 through 6, but of the increase from 2 chunks to 3 chunks of information which must be processed. Children may find it more difficult to switch from retaining 2 chunks (lengths 1 and 2) to 3 chunks (lengths 3, 4, 5 and 6). The lack of increase in errors from length 3 through length 5 may be accounted for by this theory since these children should find it no more difficult to retain increasing stimulus lengths as long as the number of chunks remains the same. Practice effects and greater facility
at the recoding process will also tend to decrease error scores. This may have occurred at length 6 with this sample, resulting in a slight decrease in error scores.

No significant differences attributable to length occurred for the simultaneous presentation although there was a tendency in this sample for the number of errors to decrease as the stimulus length increased. This may be attributable to practice effects and familiarity with the presentation format. This is speculation but consistent with the findings of Loveless, Brebner & Hamilton (1970).

Presentations and Short-Term Auditory Memory

The third-grade children were able to process auditory and visual non-verbal stimuli presented simultaneously with more facility than the same stimuli presented consecutively in the recognition task. This difference was a significant one for lengths 3, 4 and 5. The lack of significant differences at lengths 1 and 2 may be attributable to the relative ease of processing the shorter stimulus lengths (2 chunks/stimulus) and also to the children's initial adjustment to the tasks. At length 6 the increase in AVI scores for the consecutive presentation might have been due, as previously mentioned, to greater facility of the children at recoding the stimuli consisting of three chunks/stimulus resulting from practising this task at
three different lengths.

The significant differences in AVI scores between presentations both overall and as a function of length is consistent with the hypothesis that the consecutive presentation includes a factor, or factors, which inhibits children's ability to make accurate judgments of AVI. It might be argued that children would score higher on a test of AVI which presented the stimuli via two sense modalities at the same time (simultaneous presentation), implying the presence of a sensory-summing effect in learning. However, Witty and Sizemore (1958), having reviewed numerous studies of auditory and visual stimuli presentation, concluded that learning is not always facilitated by simultaneous presentation involving a combination of senses such as audition and vision. They state that sometimes a particular approach rather than a combination proved more effective. In such cases, the failure of one sensory modality to facilitate another might be attributed to the habitual tendency of the children to use and prefer one sensory modality to another.

An alternate interpretation is the presence of a short-term auditory memory factor and/or a cross-modal interference factor within auditory memory in the consecutive presentation that inhibits performance of the AVI test. This explanation is similar to the hypothesis of Sterritt & Rudnick (1966) that memory for auditory temporal patterns may be an important factor common to
performance on the AVI test. Sterritt, Martin & Rudnick (1968) and Rodenborn & Brown (1970) found auditory memory to be a significant factor in the AVI test.

The latter authors calculated the coefficient of the determination between auditory memory and AVI and found this to be 16.3 per cent. These results are contrary to those of Kahn & Birch (1968) and Ford (1967) who, using the Digit Span subtest of the Wechsler Intelligence Scale for Children to measure auditory memory, found no significant relationship between children's performance on this test and the AVI test. The present study suggests that the Digit Span test may measure other aspects of auditory memory than those involved in AVI.

The difference in AVI scores between the consecutive and simultaneous presentation is somewhat more impressive than it appears at first sight since there are a number of research findings which suggest that the consecutive presentation of this experiment was biased, due to the three repetitions of the auditory stimulus, in a direction that should favor lower error scores. Yet, for the stimulus lengths 3, 4 and 5 the consecutive presentation produced the higher error scores. Hebb (1961) and Hellyer (1962) have both stated that short-term retention improves when the material to be recalled is repeated before a test of retention, or when it is repeated between successive tests. Tulving & Madigan (1970) state that all current theories and almost all extant
data tell us that the best way to learn verbal material beyond the immediate memory span is to allow its repetition -- exactly the same item presented trial after trial.

In the present study the consecutive presentation included three repetitions of the auditory stimulus prior to exposure of the visual stimuli. The AVI test of Birch & Belmont included one repetition of the auditory stimulus. If one can assume that repetition facilitates the retention of the auditory stimulus, then the short-term auditory memory effects to be estimated between the AVI test of Birch & Belmont and the simultaneous presentation of this study would be underestimated. This underestimate would be to the degree that the three repetitions of the auditory stimulus facilitated short-term auditory memory.

Position of the Visual Stimulus

The positions of the visual stimuli had a significant effect on the recognition of auditory-visual pairs. However, the components of variance approach attributes to it an effect less than 1 per cent of the error variance. The grade three children made fewer errors of AVI when responding to stimuli in position 1 ($P_1$) and position 2 ($P_2$), than in position 3 ($P_3$). Although this effect was small, it was reliable ($P < .005$), and two alternate interpretations of the position effect will be considered. The position effect for the consecutive presentation will be considered in terms of decay and interference assumptions in short-term memory.
and proactive interference. The position effect for the simultaneous presentation will be considered in terms of the assumptions of proactive interference. It should be kept in mind that this discussion does not purport to shed light on the decay-interference controversy or on proactive interference. They are used only as a means of interpreting the present data.

A. The Consecutive Presentation

Although the auditory stimulus was repeated, which presumably would facilitate auditory memory, it was noted that children in the consecutive presentation tended to tap fingers or feet, make lip movements, etc., between the cessation of the auditory stimulus and initiation of the first visual stimulus and also during the presentation of the visual stimuli. This would appear to indicate rehearsal methods which may suggest a memory mechanism or the presence of interference. This obvious rehearsal was not noticed during the simultaneous presentation.

Waugh & Norman (1965), in their model of sensory-primary-secondary memory, reported that rapid decay of material from memory occurs only under limited experimental conditions which include the presence of some interfering (or rehearsal-preventing) task. This finding is also supported by Aaronson (1968), Brown (1955) and Sperling (1963). This suggests that the span of immediate memory is limited by a lack of opportunity to rehearse.
A possible memory system is one in which the limited capacity of immediate memory is due to difficulty in rehearsing many items at once. Rehearsal might serve both to maintain material in immediate memory and help transfer it to a more permanent store. In their discussions, Waugh & Norman place heavy emphasis on the role of rehearsal in prolonging the period of storage of material in primary memory and increasing the likelihood of entry into secondary memory.

Norman (1969) states that the vocal aspect of rehearsal implies that material is remembered in auditory form even when it was originally presented in visual form. Sperling (1963, 1967) advocated the view that visual input is translated into an auditory analogue. This view receives support from the fact that short-term memory for a series of acoustically similar items was found to be impaired when compared with acoustically dissimilar items, regardless of whether the input modality was auditory or visual (Hintzman, 1967, Murray, 1967).

It should be noted that the author has found no evidence to discount the possibility that the auditory stimulus might be translated to a visual or kinesthetic analogue dependent upon each child's preferred modality. This also suggests the possibility that the visual stimuli might be translated to either an auditory or kinesthetic analogue. The methods of approaching the AVI test mentioned by Kahn & Birch (1968) tend to support this
notion. Although this remains as a possibility the following interpretations will be made on the basis of the research findings reported above (e.g., Norman, 1969; Sperling, 1963, 1967; Hintzman, 1967; Murray, 1967).

It would appear that the visual-to-auditory analogue translation phenomenon readily occurs in the present study if children's lip movements are any indication. Each visual stimulus may be translated to an auditory analogue and the judgment as to equivalence made between the auditory stimulus and the auditory analogue. As the visual stimulus in $P_1$ is being translated to its auditory analogue, rehearsal of the auditory stimulus may be discontinued in order to avoid confusion. This break in rehearsal may result in decay and possible intra-modal interference between the auditory analogue and auditory stimulus and may tend to interfere with the retention of the auditory stimulus. This procedure would be repeated at $P_2$. The translation would again tend to discontinue rehearsal of the auditory stimulus resulting in decay and interference between the auditory stimulus and auditory analogue. The results suggest that this effect is cumulative and judgments of AVI are not impaired until $P_3$.

The decay-interference interpretation of the position effect for the consecutive presentation is consistent with the findings of proactive interference. The normal explanations for proactive interference are based on the assumptions that stimulus traces
from earlier learned material become confused with incoming traces from material presently being learned and performance on early items in a list suffer least from proactive interference effects. This approach to interpreting the position effect is similar to the interference assumptions of short-term memory. Proactive interference will be discussed further in relation to the position effect for the simultaneous presentation.

Miller's (1956) theory of recoding input stimuli is consistent with either interpretation of the position effect for the consecutive presentation. Each auditory stimulus might be recoded into chunks in order to aid retention. Each visual stimulus might also be recoded into chunks, translated to its auditory analogue and equated with the auditory stimulus carried in memory. This procedure would be repeated for each visual stimulus. The translation of each successive visual stimulus to its auditory analogue might result in decay, as a result of the interruption of rehearsal of the auditory stimulus, and interference due to intra-modal interference between the auditory stimulus and non-equivalent auditory analogues. Also the retention period, from cessation of the auditory stimulus to presentation of each visual stimulus, increases as each successive visual stimulus is presented. The decrease in AVI scores at P₃ might be due to any one of these factors, a combination, or all of them,
since the amount of decay, interference and overall retention time increases as each successive visual stimulus is processed.

B. The Simultaneous Presentation

Although it was thought that the simultaneous presentation of the auditory and visual stimuli would control for the position effect, the position of the visual stimulus was also found significant for this presentation. It will be considered on the basis of proactive interference.

The auditory-visual pair presented in $P_1$ would tend to be processed free of any interfering similar stimuli while the auditory-visual pairs in $P_2$ and $P_3$ would be subject to interference from one and two previous similar processing tasks, respectively. The interference would tend to impair subsequent AVI judgments due to the stimulus traces of the proceeding stimuli interfering with the registration of the present stimuli. This finding is consistent with those of Aaronson (1968) who reports evidence indicating that perceptual processes continue to occur after the physical stimulus presentation — either auditory or visual — is terminated. If stimulus-pairs are presented at a rate exceeding the perceptual processing rate, then memory traces from previous stimulus-pairs could interfere with the processing of the following stimulus-pairs. The evidence indicates that this effect must be thought of as cumulative and occurring following the visual stimulus.
in $P_2$. An assumption of sensory-overloading may be called upon to explain why this effect did not occur at $P_2$ also. That is, the interference of one auditory and visual stimuli-pair ($P_1$) was not sufficient to increase the probability of an error being made at the adjacent position ($P_2$) but the interference of two auditory and visual stimuli-pairs ($P_1, P_2$) was sufficient to increase this error probability for the adjacent pair ($P_3$).

Sex Differences

Most previous studies of auditory and visual information processing have not examined sex differences (e.g., Sterritt, Camp & Lipman, 1966; Sterritt, Martin & Rudnick, 1968) or have limited the sample to male subjects to eliminate sex differences known to exist in reading achievement (e.g., Rudnick, Sterritt & Flax, 1967; Ford, 1967; Senf, 1969). The present study found no significant difference in AVI scores for males and females. The overall mean AVI scores for male and female children were 5.36 and 5.19 respectively, giving a difference whose probability (if the true difference is zero) was greater than .25. The tendency for males to score higher occurred in the simultaneous presentation where their mean AVI score was 5.57 as compared to the females who obtained a mean AVI score of 5.20. The mean AVI scores of males and females for the consecutive presentation were 5.16 and
5.19 respectively. The presentation x sex (AxS) interaction yielded a probability level of greater than .25 and no other interactions involving sex were significant. These results are consistent with those of Hurley (1968) and Rodenborn & Brown (1970) who, using intersensory integration tests, have also found no indication of a sex-based difference.

Other Findings

As noted in Chapter V, there is some doubt about the significance of differences among positions of stimuli as a function of stimulus length across the three orders (OxLxP) and also across the presentation and order combinations (AxOxLxP). Because of this, and because of the complexity of these interaction effects no interpretation is attempted. Significant performance differences occurred among the groups as a function of stimulus length across presentation and order combinations (GxL/AxO). No clear interpretation of this effect could be found.
CONCLUSIONS

The results support the notion that there may be a significant short-term auditory memory factor which may include cross-modal interference in performance on the test of AVI. They also indicate that this memory component is significantly related to impairment of judgments of AVI when compared with results of an AVI test which reduces auditory memory as a factor. Third grade children are able to process the simultaneous presentation of auditory and visual non-verbal stimuli at certain stimulus lengths with more facility than they are when the same stimuli are presented in a consecutive manner. Although some previous studies using popular tests of auditory memory have found no significant relationship with performance on the test of AVI, the present evidence suggests that the auditory memory tests previously employed may measure a different aspect, or aspects, of auditory memory than those involved in the performance on the AVI test.

Another finding indicates that stimulus length per se may not be a significant factor affecting the difficulty of AVI judgments, but that a factor related to length may be. The results are consistent with a theory (Miller, 1956) of recoding input stimuli and suggest that an increase in the number of units of stimuli to be retained, and not the number of stimuli per unit,
may be the factor affecting the difficulty level of AVI judgments.

The position of the visual stimuli was also found to affect the recognition of auditory and visual pairs in the AVI test. This effect, small though significant, occurred for both the consecutive and simultaneous presentations, indicating that interference or decay of sensory processing does occur whether the presentation is consecutive or simultaneous for stimuli in P₃. It is suggested that the assumptions of interference and/or decay in short-term memory and proactive interference, may account for the impaired ability to make correct judgments of AVI for stimuli in position three as compared to stimuli in position one and position two for the consecutive presentation. The assumption of proactive interference is suggested to account for the similar phenomenon occurring in the simultaneous presentation.

RESEARCH CONSIDERATIONS

Further study of the differences between the consecutive and simultaneous presentations might be undertaken to establish whether the present findings also apply to children at other age-grade levels. The simultaneous presentation should be examined to determine whether the ability it is measuring is significantly related to reading processes at different age-grade levels.
The simultaneous presentation of auditory and visual stimuli may facilitate learning for some children due to the elimination of memory as a factor and also due to any facilitative effect one modality may have for another for any particular child. This does not say, however, that the simultaneous presentation will be related significantly to any of the reading processes at any age-grade level. It may be more reliable as an instrument for determining the most efficient way a child learns rather than as a diagnostic tool specifically related to reading.

In order to examine more thoroughly and attempt to account for a number of the present findings, further research might investigate the effects of stimulus length and stimulus position. Since stimulus length (bits/stimulus) appeared to affect significantly the AVI judgments for the consecutive presentation and the results could be accounted for by a recoding or chunking theory, it would be interesting to increase the number of chunks per stimulus independently of the number of dots per stimulus length. This would be done to determine whether the increase in the number of chunks did in fact impair AVI judgments. A decrease in AVI scores would be predicted to occur for each increase in the number chunks. An increase in AVI scores would be predicted to occur as the number of trials increased and a subsequent decrease to occur when the number of chunks increased. It would also be interesting to increase the number of dots per chunk to determine
what limit, if any, there is to the number of pieces of information per chunk that can be recoded and retained. The number of chunks that can be recoded and retained could also be estimated by systematically increasing the number of chunks per stimulus.

Position effects for the consecutive presentation could be further examined by increasing the number of visual stimuli, and thus increasing the possible interference and decay factors of short-term memory to determine whether AVI performance deteriorates as the number of potentially interfering factors increases. If this did occur it would lend more support to the assumption concerning interference and decay effects of intervening stimuli.

Position effects for the simultaneous presentation could also be further examined by increasing the interstimulus interval to determine whether the possible influences of proactive interference decrease as this interval increases, and vice versa. This design would tend to allow more time for perceptual processing of previous stimuli to terminate and thus decrease the interference effect.
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APPENDIX A

TEST INSTRUCTIONS

Presentation A

After seating the Ss and gaining their attention, the E said, "I'm going to tap out some patterns. Listen." Three examples, a, b, and c were tapped with a pause of 3-sec between examples. The Ss were then shown (on a screen) example a and told "Each pattern you hear is going to be like a dot pattern you will see on the screen. Now we will practice. You will hear the same dot pattern three times. I will say 'ready' before they begin and when they have ended I will say 'Now you will see the dots on the screen.' You will be shown three different dot patterns, one at a time. You are to tell me if each pattern is the same or not the same as the pattern you just heard. I will say 'number one, number two or number three before each dot pattern is shown so you will be ready. As you make a decision for number one, number two and number three, you will put either a 'yes' or a 'no' on the answer sheet under this number. 'Yes' means they are the same and 'no' means they are not the same. I will tell you which number we are on before each tap pattern you hear."
After the Ss listened to the instructions, E said "let's try example a." Example a was presented again with three repetitions and the Ss were shown three visual patterns successively. E then asked "Let's see if you did that one correctly. Do you think number one was the same or not the same?" Simultaneously with the Ss' response and independently of their choices, E told them the correct answer and said "It's the same (or not the same)." This procedure was repeated for numbers two and three. For the next two examples, b and c, E said "Listen again and you write down whether each one is the same or not the same. Remember put 'yes' if they are the same and 'no' if they are not the same." In each instance, E presented the auditory pattern and asked "Was number one the same or not the same?" After the presentation of examples a, b and c, the 18 tasks of the test were given.

The Ss were told, "Now that you know how to do it, I want you to listen carefully and pick out the dots which look like the taps you hear." E instructed the Ss to listen before each new auditory pattern and also signaled the onset of the visual patterns. Only first choices were accepted and no changes in response were permitted in order to eliminate comparisons among the visual stimuli.

Presentation A2

Preliminary instructions and the introduction to the
tap and dot patterns were the same as Presentation $A_1$. E told the Ss for Presentation $A_2$ "You will hear the same dot pattern three times and each time you hear it you will see a dot pattern on the screen. I will say 'ready' before the dot pattern begins and tell you whether the dot pattern you are seeing is number one, number two or number three. You are to decide whether the one you see is the same or not the same as the one you hear. When you have decided number one, number two and number three as the same or not the same, you will put either a 'yes' for the same, or a 'no' for not the same on the answer sheet under each number. I will tell you which number we are on before each dot pattern you hear."

After the Ss listened to the instructions E said "Let's try example a." Example a was presented three times with three visual dot patterns.

The instructions following this were the same as those for Presentation $A_1$. 