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The first step in learning to read is to recognize the visual language code as equivalent to the auditory code. The next step is the translation between auditory and visual information as well as between temporal and spatial organizations. The factors contributing to such translations are divided into six subprocesses: auditory sequence perception, visual sequence perception, temporal sequence perception, spatial sequence perception, audiovisual integration, and temporal-spatial integration. Nine tests were devised to measure the ability of 40 third graders in these six subprocesses. The tests were based on sequences of dots or beeps to be paired with or differentiated from other sequences. It was hypothesized that the three tests based on the subprocesses requiring no translation would be the easiest; this hypothesis was not confirmed. Difficulty was determined by the stimulus modality of the first pattern which had to be remembered for comparison with the second. A mean of 2.43 errors occurred on tests having a visual-spatial pattern first. A mean of 5.35 errors occurred when an auditory-temporal or visual-temporal pattern was first. Sequence perception scores showed low relationships with reading scores. (WL)

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Sequential Pattern Perception and Reading*

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For some time we have been investigating children's accuracy in perceiving sequential patterns (4,5). In some of this work we have asked children to compare information given in auditory form with other information presented visually. The child's ability to make such comparisons across sensory modalities has been referred to as "auditory-visual integration" ability (1,2).

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.,--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 auditory-visual integration, we are usually also referring to temporal-spatial integration--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 have pointed out that when the child reaches school age, he has previously acquired an auditory language--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.

Translation, however, requires competence in both of the language-codes involved. If failures occur in translation, the reason may be simply that the child has trouble with one (and only one) of the codes, or purely with the other code, or he may have trouble with neither code, alone, but only with the integration process by which he makes associations between the codes. We have analyzed this complicated process into a set of six simpler sub-processes, each of which is in some sense crucial to reading:

1. auditory sequence perception
2. visual sequence perception
3. temporal sequence perception
4. spatial sequence perception
5. auditory-visual integration
6. temporal-spatial integration

So as to make the tests easier to interpret, we have employed only very simplified forms of sequential stimuli. For example, by a "visual-spatial pattern", we mean simply a printed sequence of dots, with long and short spaces between, forming a definite visual-spatial array, while by an "auditory-temporal" pattern we mean only a series of brief "beeps", presented through headphones, with long or short pauses between beeps, forming a definite pattern in time. We have also employed "visual-temporal" patterns, delivered in the form of a series of brief flashes of a light with long or short pauses between. Thus we have presented equivalent temporal patterns in auditory and in visual form, and visual patterns in temporal and in spatial form. In addition, however, we have also presented combinations, such as an auditory-temporal pattern followed by a visual-spatial pattern. The sequence of dots making up the two patterns may in fact be exactly identical or they may be slightly different, as in one having one more dot than the other or a slightly different distribution of long and short spaces within the sequence. The child's task is to attend to the two sequential presentations and say whether the two patterns were exactly the same or different. We have devised a total of nine such tests.

It is possible to give one child the entire series of nine tests. Because the patterns in any of the tests are made up purely of dots and spaces, and since the different tests employ different sets of dot patterns which are of equivalent difficulty, any differences which emerge in one child's pattern of successes and failures on the nine tests should reflect his own pattern of relative perceptual strengths and weaknesses. More specifically, the procedure was as follows.

PROCEDURE

The subjects (Ss) of this research were 40 children, 20 girls and 20 boys from the third grade of a school in the same district studied previously (4,5). The mean age was 109 mos., S. D. = 6.6 mos., range 101 to 126 mos. Ss were from predominantly upper middle class, Caucasian families. Permission to include the children in this research was granted by the parents of every child in the third grade. Random procedures were used to select 10 girls and 10 boys above their respective medians in intelligence, and 10 of each sex below median intelligence.

Every S was given 10 perceptual tests, the 9 described above and the B-B test (1) in the counterbalanced order. The BB test was given in the same modified form used previously by us (4,5). A test consisted of 5 practice and 18 test items. In all except the B-B test, a test item contained a pair of dot patterns, and S was asked if the first pattern was the same or different than the second pattern (e.g., "... .." is the same as "... .." while ".. ..." is different from ". ...."). At the easiest end of the scale, one pattern consisted of a single group of 2 to 4 dots. Successive items had larger numbers of dots up to a maximum of 5 groups of 1 to 4 dots per pattern.

The stimulus modalities employed in each of the nine tests and the translations required in each test were as follows:

Test 1, auditory-temporal to visual spatial, 2 translations (A→V and T→S)
Test 2, visual-spatial to auditory temporal, 2 translations (V→A and S→T)
Test 3, auditory-temporal to visual-temporal, 1 translation (A→V)
Test 4, visual-temporal to auditory-temporal, 1 translation (V→A)
Test 5, visual-temporal to visual-spatial, 1 translation (T→S)
Test 6, visual-spatial to visual-temporal, 1 translation (S→T)
Test 7, auditory-temporal to auditory-temporal, no translation
Test 8, visual-temporal to visual-temporal, no translation
Test 9, visual-spatial to visual-spatial, no translation

Auditory-temporal pattern were presented via headphones using tones approximately 1000 Hz at 60 db (re audiometric zero) for the first pattern and 1200 Hz at 60 db for the second pattern. Visual-temporal patterns were flashed out by two NE 34 lamps, one lamp for the first and the other for the second pattern. (Separate frequencies and separate lamps were used for the first and second patterns to make it easier for the children to know when the first pattern ended and the second began.) The light or tone was on for 0.2 sec. and off for 0.4 sec. (short pause) or 1.0 sec. (long pause). A pause of 2.8 sec. occurred between the end of the first pattern and the start of the second. Visual-spatial dot patterns were presented in the form of printed lines of dots, one pattern per page. When the first pattern of a pair was a VS pattern, Ss almost always glanced at the page and then looked up in anticipation of the second pattern. The examiner used this cue to initiate the exposure of the second pattern. When the VS pattern was second, the page was exposed after the end of the first pattern and left exposed until S responded (usually a very short time). The printed dots were 2 mm diameter with 2 mm (short space) or 8 mm (long space) between dots. For test 9, (VS-VS) the two patterns of the pair were printed on successive pages with a blank page exposed between the patterns of one pair.

Nine equivalent test "forms" were counterbalanced across the nine kinds of tests so that every child got each form once and only once.

Each test took roughly 10 minutes. Two groups of three and one group of four tests were given, with approximately 12 days between test sessions.

The entire group of 10 perceptual tests were given in A·il and May when the children were near the end of third grade, and then repeated identically in October and November, after the same children had started fourth grade. Four children moved and the parents of two of the children did not give permission for retesting, reducing to 34 children the number of children who received both sets of individual tests. (Matched substitutions were made for the missing children to complete the experimental design for purposes of some kinds of statistical analysis, but no substitutions were included in the analysis of test-retest reliability).

One procedural error occurred in the administration of the perceptual tests. The covers of two visual-spatial dot pattern books were interchanged with the result that the temporal patterns were not coordinated with the spatial patterns on 38 out of the total of 400 test presentations, affecting four kinds of tests (#1, 2, 5, and 6). It was still possible to determine the score earned on each of the affected tests, however, and a demonstrably unbiased correction procedure was applied to the earned scores to estimate the score which each child would have obtained had the procedural error not occurred.

Group administered tests of intelligence, perception and reading ability were given before the spring individual test sessions. Certain of these were repeated after the fall individual tests.

Group tests given only in the spring were (a) the SRA Primary Mental Abilities Test for grades 2-4; (b) the California Short-Form Test of Mental Maturity, 1963 S form, level 1H; (c) the Metropolitan Elementary Reading Test, Form A; (d) a test of visual (letter-like) form discrimination, modified from Gibson (3); (e) the Wepman (6) test of auditory discrimination Form I; and (f) a specially constructed sight vocabulary test (designed to minimize auditory-auditory or visual-visual confusion so as to maximize sensitivity to auditory-visual "translation" failures as a source of errors in reading).

Group tests given in the spring and fall were: (a) a phonics-analysis test measuring the ability to analyze the beginning and ending-sounds of words, modified from Part A of the Word-Study Skills subtest of the Stanford Achievement Test, Primary II); and (b) the "Visual Phonics" (Part B) subtest from the Word Study Skills subtest of the Stanford Achievement Test (requiring that the child identify the sound made by an underlined letter in a word, then find the one of three printed words which contained the same sound).

In addition to all of these tests administered by the research team, scores from several other tests were made available from school records. These were (a) the Lorge-Thorndike Intelligence Scale level I-form A, administered Sept. 1966, at the beginning of the third grade school year; (b) the Iowa Tests of Basic Skills, Form 1, administered in February (two months before the spring individual testing); and (c) the Iowa Tests of Basic Skills, Form 2, administered in January 1968, two months after the fall individual testing. (Two more children moved before the last Iowa testing, reducing the number receiving the entire battery to 32.) All of the children had passed a screening test of hearing at 15 db, re audiometric zero, at several frequencies.

Results and Discussion

As expected, the children proved to be above average in intelligence and school achievement, and showed good improvement in phonics skills, reading vocabulary, reading comprehension, and spelling, from the first to the last test. However, individual differences in intelligence and achievement were very great. (Lorge-Thorndike IQ's were as low as 73 and as high as 134, and in reading comprehension the least capable child was at grade level 1.9, while the best was at the 6.1 grade-level at the time of the initial Iowa testing in February 1967, when all Ss were in the middle of the third grade).

Almost all of the children earned perfect or near-perfect scores on the Wepman and modified Gibson tests, indicating that few, if any, of the children had important problems at the level of speech discrimination or visual form discrimination.

Before introducing the results of the sequence-perception tests, it would be well to review some of the points mentioned in the introduction. Those perceptual tests would seem to be easiest in which both patterns are presented in the same stimulus modality—that is, in which both patterns consist of tones presented via headphones, or both consist of flashing lights, or both are printed dot patterns. In fact, one could argue that presenting the second pattern in a different stimulus modality makes the task three times as likely to be troublesome to the child for the following reasons: when both patterns are in the same modality there is only the one possibility that the given modality may be a difficult one for a given child. But when the first and second patterns are in different modalities, the child can have trouble because the first stimulus modality is difficult for him, or because the second modality is one that he has trouble with, or because he has problems in "translating" between different stimulus modalities.

On the basis of this reasoning, we hypothesized that the easiest sequence-perception tests should be the three which require no translations, Test 7 (AT-AT), 8 (VT-VT) and 9 (VS-VS). Four tests were expected to be more difficult. These were Tests 3 and 4, which require auditory-visual or visual-auditory translation, and Tests 5 and 6, which require temporal-spatial or spatial-temporal translation. Most difficult of all, by this line of reasoning, would be Test 1 (AT-VS) and Test 2 (VS-AT), since each of these tests requires all 6 of the sequence perception subcategories listed in the introduction.

We believe that the arguments in the preceding paragraph are reasonable and logically consistent. The results actually obtained, however, make it clear that these reasonable expectations simply are not borne out by the facts. The results obtained in the spring and in the fall resembled each other fairly closely, but little resemblance was found between the expected results and either set of obtained results. Tests 1 and 2, expected to be the most difficult ones, were in fact far out of the expected range, below the median level of difficulty. Only two of the tests which were expected to be intermediate in difficulty were so, one of the others being in the most- and one in the least-difficult range. And only one of the three tests expected to be in the easiest range actually fell there, one other falling in the hardest range and one in the intermediate range.

Thus, one logically consistent way of looking at sequence-perception tests has been tried and found wanting. In this because the data are chaotic, or is there a way of conceptualizing these tests, according to which the obtained results do organize themselves in an orderly and logically consistent way? One of us (V.E.M.) deserves credit for discovering that th results do follow a consistent pattern, which is as follows:

(1) The difficulty level of the sequence-perception tests is determined primarily by the stimulus modality of the pattern which is presented first, the pattern which must be carried in memory, and to a lesser degree by the stimulus modality of the second pattern, in which memory is much less of a factor.

(2) Visual-spatial patterns are much easier than auditory-temporal or visual-temporal patterns, (e.g. in the spring test results a mean of 2.43 errors occurred on the tests in which the first pattern was visual-spatial, while a mean of 5.35 errors occurred on the tests in which the first pattern was auditory-temporal or visual-temporal). The results of the analyses of variance of perceptual test scores demonstrated that these findings were very reliable, statistically, in spring and in fall results.

The test-retest reliability of the perceptual tests proved to be relatively low over the 7-months interval between test and retest, ranging from a low of .19 for Test 7 to a high of .51 for Test 6. (The BB test was more reliable, r = .62). Reliabilities were generally improved, however, when scores on similar tests were combined, e.g. each child's total number of errors on all 9 tests together, test-retest r = .68.

So much for the difficulty levels and reliabilities of the tests. Now let us consider the results from an entirely different viewpoint, that of the relationships among the various tests of intelligence, perception, and reading ability.

Intelligence generally predicted reading scores very well. Especially impressive were the predictions of reading in the middle of the fourth grade by a group test of intelligence (albeit one which involves reading) given at the start of the third grade (Lorge-Thorndike Total IQ, September 1966, with Iowa Reading Comprehension, January 1968, r = .74, p < .001, 55% of reading variance accounted for). Children who read well (and those who read poorly) in the middle of third grade generally still did so in the middle of fourth grade, as shown by very high correlations of earlier with later reading scores;(e.g., earlier with later Iowa Reading Comprehension, $r = .88$, 77% of reading variance accounted for).

By contrast, sequence perception scores show relatively low relationships to reading scores. In fact, only two perceptual tests, #4 (VT-AT) and #7 (AT-AT) show significant correlations with 7 to 9-months-later reading scores (April '67 Test 4 scores with Jan. '68 Iowa Reading scores, $r = .41$, $p < .05$; April '67 Test 7 scores with Nov. '67 Phonics Analysis scores, $r = .55$, $p < .01$).

If reliability is improved when scores on similar perceptual tests are combined, then correlations of combined perceptual test scores, with reading, might be expected to be higher than correlations of individual perceptual test scores with reading. Combined perceptual test scores were indeed more highly related to reading on the average, but only in relation to phonics analysis acores, not to reading comprehension (mean correlation of 10 individual perceptual tests with phonics scores, $r = .25$, with reading comprehension, $r = .23$; mean correlation of 15 perceptual scores derived by combining scores from related tests, with phonics scores, $r = .39$, with reading comprehension, $r = .24$).

It is interesting that the relationships of the various combined perceptual scores to phonics scores appeared to become stronger, from lower correlations of early combined perceptual with early phonics scores (mean $r = .33$), to somewhat higher predictive relationships of early perceptual scores with later phonics scores (mean $r = .36$), to still higher correlations of later perceptual with later phonics scores (mean $r = .49$) . In the relationships of later combined perceptual scores to later phonics scores, 12 correlations were significant at the .01 level and the remaining three were significant at the .05 level.

More specific conclusions about which sequence-perceptual abilities, among the six listed in the introduction, are most strongly related to reading, would appear to be hazardous. Tests requiring no translations related about as strongly as the rest, and high correlations with reading occurred using some tests requiring visual, some demanding auditory, some involving temporal and some requiring spatial pattern perceptual abilities. Thus it appears possible that some feature common to all of the sequence-perceptual tests may be the most important factor explaining the relationships of these tests to reading. Alternatively, it would seem very possible that different children have trouble learning to read for different reasons. If so, this would tend to reduce the relationship of any one perceptual factor to reading achievement. In any event, the data certainly cast doubt upon the view that any one of the six perceptual abilities listed in the introduction is much more related than the rest to individual differences in reading ability at the third grade level.

The results of this research are being analyzed further from several standpoints. Multiple regression equations are under construction for analysis of the independent contributions of intelligence and perceptual abilities to the determination of reading ability. The perceptual test data may be factor-analyzed, and a "critical scores" approach to the differentiation of higher from lower readers will be attempted. A "perceptual profile" was constructed for each child, and these are being studied in relation to school achievement. In addition, the entire battery of tests described here has been administered to a sample of first graders and a sample of fifth graders.

It is hoped that this program, when completed, will yield a clearer picture than has previously been available, of the role of various kinds of sequence-perceptual abilities in the development of reading skills.

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