Auditory-visual and temporal-spatial integration as determinants of test difficulty*

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Perceptual tests were administered to children during the summer before they entered first grade. Some tests required comparison of visual with auditory stimuli, and other tests required comparison of temporally patterned with spatially patterned stimuli. Several tests involved both of these kinds of perceptual comparison, while other tests involved neither. Mean error scores on the various tests indicated that spatial patterns are perceived or remembered more readily than temporal patterns. Neither auditory-visual nor temporal-spatial integration, however, appears more difficult than similar comparisons involving no integrations.

Chalfant & Scheffelin (1969) noted that research on intersensory integration has been limited, despite the potential social usefulness of findings from this area of investigation. Among a number of fields to which such research might be applied, learning to read is dependent not only on smooth auditory and visual perceptual functioning, but presumably also involves cooperative functioning between these two sense modalities. In this sense, reading may be understood as an "intersensory integrative" task. Research on intersensory functioning might influence, in helpful ways, the manner in which reading is taught.

Theoretical discussions of intersensory integrative processes, the study of which has received impetus from the work of Herbert Birch during the past decade, have suggested that intersensory integration is a higher order ability which develops later than intrasensory functioning and that the former is somehow dependent on the latter (e.g., Birch, 1954; Birch & Lefford, 1963; Belmont, Birch, & Karp, 1965; Birch & Belmont, 1965). Other observations and investigations would suggest, however, that some kinds of intersensory integration may *not* be more difficult than corresponding intrasensory functioning, even for young children (e.g., Piaget, 1952; Muehl & Kremenak, 1966).

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The research described here is an effort to extend the study of the separate influences of certain temporal and spatial aspects of simple auditory and visual perception, as well as intersensory integration, as determinants of perceptual test difficulty for young children (Sterritt & Rudnick, 1966; Rudnick, Sterritt, & Flax, 1967).

PROCEDURE

A battery of nine perceptual tests was constructed. The tests, types, and numbers of integrations required in each test are summarized in Table 1.

Test 1 involves comparison of auditory-temporal (AT) with visual-spatial (VS) patterns. The child listens to an AT pattern, and after it ends, he is shown a single VS pattern and asked whether the two patterns are the same or different. Test 2 is the same except that the VS pattern comes first and the AT second. Each of these two tests requires auditory perception, visual perception, temporal pattern perception, spatial pattern perception, auditory-visual integration, and temporal-spatial integration. The next four tests require only one kind of integration at a time. That is, Tests 3 and 4 require comparison of auditory with visual patterns, all of which are temporal (AT to VT and VT to AT), while Tests 5 and 6 require comparison of temporally with spatially arranged patterns (VT to VS and VS to VT), all of which are visual. The last three tests require only intrasensory comparisons and not intersensory integration (AT to AT, VT to VT, and VS to VS).

AT patterns were presented via headphones, using tones approximately 1,000 Hz at 60 dB (re: audiometric zero) for the first pattern and 1,200 Hz at 60 dB for the second pattern. VT patterns were flashed 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. VS dot patterns were presented in the form of printed lines of dots, one pattern per page. The printed dots were 2 mm in diam, with 2 mm (short space) or 8 mm (long space) between dots. For Test 9 (VS to VS), the two patterns of the pair were printed on separate pages, with a blank page exposed momentarily (approximately ½ sec) between the patterns of one pair. 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 E 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).

Every S received only one type of perceptual test. Each test consisted of two forms given to each child in counterbalanced order. Time between administrations of each form for each child was 1 or 2 days. Each form consisted of Parts A, B, C, and D.

Part A included two sets of six items. Each item contained from 1 to 12 "bits" (beeps, flashes, or dots) to be counted by the child. The first set of six items was given in the first modality, while the second set of six was given in the second modality (e.g., in Test 1, AT to VS, the first set was AT and the second set was VS). If the second modality was the same as the first (e.g., Test 7, AT to AT), the child received both sets in the same modality (AT and AT). A standard set of instructions told the children to count the number of beeps, flashes, or dots, depending on the test, and to report the total number counted.

Part B included 12 items. Bits were given first in one modality (the same modality as in the first set of Part A) and then in the second modality (like the second set of Part A). Standard instructions included directions to compare the number of bits in the first with the number in the second modality and to report whether they were the same or different. The number of bits in each item to be compared ranged from one and one to six and six.

Part C included two sets of six items. The first set was given in the

Table 1
Means and Standard Deviations of Error Scores for Nine Perceptual Tests

	Test Number								
	1	2	3	4	5	6	7	8	9
Perceptual Comparisons	AT-VS	VS-AT	AT-VT	VT-AT	VT-VS	VS-VT	AT-AT	VT-VT	VS-VS
Numbers of Integrations	2	2	1	1	1	1	0	0	0
Kinds of Integrations	A to V and T to S	V to A and S to T	A to V	V to A	T to S	S to T			
N	7	6	7	8	6	8	8	8	8
Mean Errors	18.43	14.50	17.43	21.50	19.67	20.12	19.00	21.50	10.00
SD of Errors	7.06	6.49	3.20	4.16	4.75	5.61	5.35	4.76	4.54

first modality, the second set in the second modality. The task in Part C, however, was to count the number of *groups* of bits. The number of groups in an item ranged from two to four. The child was instructed to count the number of "bunches" of beeps, flashes, or dots. In Part C, as in Part A, the child counted and reported the number but did not compare counts.

Part D included 12 items in which the child compared one pattern to a second pattern in the same or a different modality. The child was instructed to respond with "same" or "different" to the patterns. The difficulty level of the 12 items ranged from comparing three bits (e.g., . . . to . . .) to comparing seven bits in as many as three groups (e.g., ... to . . . .). This part most resembled tests employed in prior research along these lines.

In all four parts of the test, the E said, "Right," and gave the children a trinket or a piece of candy when they were correct. After each incorrect response, the child was given no reward, and the E said, "No," and, "Let's try the next one." Each child was encouraged as necessary. The child's attention was drawn to the stimulus emitter before each item. Short rests were sometimes necessary between parts of the test.

SUBJECTS

The Ss were black children, living in an impoverished, predominantly black neighborhood, who had participated in Project Headstart and attended kindergarten in public schools. They were contacted by a paid aide living in the neighborhood, and parental permission was obtained. Testing was done during the summer months in space provided in four churches in the nieghborhood. Sensory modalities of all Ss were tested and found to be grossly intact.

Of the total group of 72 children in the design (four boys and four girls times nine tests), six had to be deleted when it was found later that they had not met criteria for selection (e.g., some had not attended kindergarten and entered kindergarten rather than first grade in September, one was found to be retarded and entered a special education class in September, etc.) or had moved and thus were not available for followups. Selection criteria were verified for all remaining Ss, all of whom were available for at least one followup testing session measuring intelligence and reading or readiness (paper in preparation).

RESULTS

Perceptual integration effects could occur only on Parts B and D of those tests which involved auditory-visual and/or temporal-spatial integration. For this reason, the statistics reported here reflect the sum of scores earned on Parts B and D. The same model analysis of variance was performed on Parts B and D, separately, as well as the sum of B + D, with essentially identical results.

Preliminary analyses were made on the forms and sessions variables. Forms 1 and 2 correlated +.85 ($p < .001$) and scores on Session 1 correlated +.87 ($p < .001$) with Session 2 scores. The forms did not differ in mean errors ($t = 1.05$, $df = 64$, $p > .10$), but more errors were made in Session 1 than in Session 2 ($t = 3.25$, $df = 64$, $p < .001$), suggesting that some learning occurred which benefited performance on Session 2. Since every pupil received the same test (opposite forms) in the two sessions, forms and sessions could be combined without introducing bias, to simplify the main analysis. This yielded a two-factor, fixed-effects-model analysis of variance with disproportionate cell frequencies. Combinations of the two sexes with nine perceptual tests gave 18 cells. A general least-squares solution was performed. Means and standard deviations for the tests are given in Table 1.

A significant main effect was found, associated with tests ($F = 4.30$, $df = 8,48$, $p < .001$). No other main effects or interactions were significant. Planned comparisons following analysis of variance (Hays, 1963) were made in order to test the following major hypotheses. Results of statistical tests are presented along with each hypothesis.

Hypothesis 1

In perceptual comparisons of purely temporal patterns, auditory-visual integration (AVI) is more difficult than auditory or visual intrasensory comparison.

In the four tests (3, 4, 7, and 8) which provide a factorially counterbalanced test of this hypothesis, the number of errors on intersensory tests (Tests 3 and 4, $M = 19.60$ errors) did not differ ($t = 0.45$, $df = 48$, $p > .30$) from errors on intrasensory tests (Tests 7 and 8, $M = 20.25$ errors).

Hypothesis 2

In perceptual comparisons of visual patterns, temporal-spatial integration (TSI) is more difficult than purely temporal or purely spatial pattern comparison.

In the four tests (5, 6, 8, and 9) which provide a factorially counterbalanced test of this hypothesis, significantly more errors occurred ($t = 2.34$, $df = 48$, $p < .01$) when TSI was required (Tests 5 and 6, $M = 19.93$ errors) than when TSI was not involved (Tests 8 and 9, $M = 15.75$ errors). Inspection of these results, however, reveals that most errors were made on Test 8 ($M = 21.50$ errors), a test which did *not* involve TSI. Thus, it is obviously the extreme ease of Test 9 ($M = 10.00$ errors) and not the factor of TSI which explains this result.

Hypothesis 3

Perceptual comparisons requiring simultaneous AVI and TSI are more difficult than comparisons involving only one or none of these integrations.

The two tests requiring two simultaneous integrations (Tests 1 and 2, $M = 16.62$ errors) were not harder than the four (Tests 3, 4, 5, and 6, $M = 19.76$ errors) requiring only one integration. In fact, the dual-integration tests proved significantly *easier* than single-integration tests ($t = 1.99$, $df = 48$, $p < .05$; we have no explanation of this finding and assume it is an artifact). The two tests requiring two simultaneous integrations (Tests 1 and 2, $M = 16.62$ errors) did not differ from the three involving no integrations (Tests 7, 8, and 9, $M = 16.83$ errors, $t = 0.22$, $df = 48$, $p > .40$). Single-integration tests (Tests 3, 4, 5, and 6, $M = 19.76$ errors) were more difficult than no-integration tests. But again, this result is clearly due to the purely spatial test (Test 9, $M = 10.00$ errors), which was significantly easier ($t = 4.91$, $df = 48$, $p < .001$) than the temporal no-integration tests (Tests 7 and 8, $M = 20.25$ errors). When Test 9 was omitted, the no-integration tests did not differ from the single-integration tests ($t = 0.38$, $df = 48$, $p > .30$).

Hypothesis 4

Perceptual comparisons of purely spatial patterns are easier than comparisons of VS with temporal patterns, which are, in turn, easier than comparisons among purely temporal patterns.

Test 9, the only purely spatial test ($M = 10.00$ errors), proved much easier ($t = 4.21$, $df = 48$, $p < .001$) than the four tests which involved both temporal and spatial patterns (Tests 1, 2, 5, and 6, $M = 18.33$ errors). These tests were easier to a degree which approached conventional criteria of statistical significance ($t = 1.32$, $df = 48$, $p < .10$) in comparison to the four tests involving only temporal patterns (Tests 3, 4, 7, and 8, $M = 19.94$ errors).

DISCUSSION

The results of this study offer no support for the hypothesis that either type of integration, AV or TS, is more difficult than similar perceptual comparisons not involving integration.

The results suggest, instead, a simple continuum of difficulty, in which comparisons among purely VS patterns are easiest, integrative comparisons of VS with temporal (auditory or visual) patterns are *not* hardest, but intermediate in difficulty, while comparisons involving only temporal patterns are most difficult *and are equally difficult whether auditory-visual integration is or is not involved.*

Strauss & Kephart (1955) and Bateman (1968) have called attention to the extreme importance of the TS distinction in perception. Muehl & Kremenak (1966) suggested that spatial patterns may be easier to perceive and recall than temporal patterns and note that this factor might explain why more errors were made on auditory (temporal) than on visual (spatial) items in their tests (footnote, p. 236). Muehl and Kremenak did not test this hypothesis, however, since in their study all auditory stimuli were temporal, while visual stimuli were exclusively spatial. Thus, the present study provides a heretofore unavailable operational separation of the AV from the TS dimension. The results of this study fully support the Muehl and Kremenak suggestion. In addition, the results independently replicate Muehl and Kremenak's experimental finding that AT-VS perceptual integration is *not* the most difficult, but rather is intermediate in difficulty between the two types of nonintegrative perceptual comparisons which they studied.

Prior discussions of this line of development may have erred doubly in speaking of "auditory-visual integration" as a critical developmental hurdle:

(1) In prior research, the AV distinction was confounded with the TS factor in such a way as to make it impossible to assess which was significant. The present results point strongly toward the TS distinction as the more significant determinant of perceptual difficulty for young children. Thus, the earlier emphasis on the AV variable may have diverted attention from the more important TS factor.

(2) Moreover, when other variables are controlled, the factor of "integration" appears to be of little or no significance in determining test difficulty for young children; i.e., integrative tasks of the kinds considered here are *not* more difficult than comparable perceptual tasks requiring no integrations, whether AV, TS, or both types of integration are considered.

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