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MONOGRAPH

COGNITIVE FACTORS IN THE RECOGNITION OF AMBIGUOUS AUDITORY AND VISUAL STIMULI [1]

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Ss were asked to identify ambiguous auditory and visual stimuli (words and pictures), each of which was presented for a series of consecutive trials. On successive trials, the degree of ambiguity (auditory masking or amount of blur) was reduced, so that on the final presentation, the stimulus was easily recognizable. The Ss were divided into 2 grps.; the WRA (wide range of ambiguity) grp. was given a series of 15 trials on each stimulus, while the NRA (narrow range of ambiguity) grp. was given fewer trials, starting at a lesser degree of ambiguity. It was found that the NRA grp. recognized the ambiguous stimuli earlier than did the WRA grp., indicating that an initial misinterpretation of an ambiguous stimulus can interfere with its later veridical recognition. Performance on the recognition tasks was predictable from scores on a set of cognitive factors, among them flexibility of closure (field dependence-independence) and cognitive flexibility-rigidity.

PROBLEM

Ambiguity involves a relation between a perceiver and an object of perception: it exists whenever a perceiver, in attempting to interpret or impart meaning to an object, finds that the object is capable of being understood in more than one way. A perceptual object will be ambiguous if it is obscure and indistinct to the perceiver, or if it implies a clear set of alternative interpretations.

While the presence of ambiguity in perception depends to a large extent on characteristics of the stimulus object, there are experiential factors, as well, which can determine whether or not a stimulus will be perceived as ambiguous within a given perceptual context. Consider, for instance, a situation in which subjects are asked to identify photographs of objects which have been rendered obscure by being thrown out of focus. An initial exposure to such an out-of-focus visual stimulus, once it has been misinterpreted by a subject, will interfere with the subsequent recognition of the stimulus object as it comes slowly into focus. Subjects who have been exposed to a highly blurred

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image will show a substantial delay in recognition if, while attempting to recognize that image, they have been kept ignorant about the correctness of their conjectures. In this situation, the ambiguity of the image at any particular moment clearly depends upon the subject's history of hypothesizing about the blurred stimulus as well as upon its degree of focus at that moment.

The adverse effect of early exposure to ambiguity upon subsequent recognition of ambiguous visual images was first demonstrated by Galloway (1946) and was later replicated by Wyatt and Campbell (1951), who used instructions designed to ensure that the subjects were attempting to perceive the objects veridically. Bruner and Potter (1964) have criticized these previous studies on the grounds that two variables have in each case been confounded: namely, the overall exposure time and the focus range of viewing. Using an analysis-of-variance design, they were able to confirm the finding that previous exposure to a highly blurred image interferes with recognition. In addition, they found the extent to which recognition is delayed depends on the overall time spent in viewing the picture: when the viewing time was shortened, recognition occurred later than when the viewing time was more prolonged. The interference phenomenon has been demonstrated using auditory stimuli as well. Blake and Vanderplas (1950) demonstrated that nonveridical recognition of a word presented at a subthreshold loudness elevated the intensity level necessary to achieve correct recognition of the word. They found the mean stimulus intensity for recognition to be significantly higher when subjects had made nonveridical hypotheses prior to recognition, than when no such hypotheses had been ventured. On the basis of these findings, they concluded that the formation of a strong, prerecognition hypothesis is a necessary prerequisite for interference in perceptual recognition.

While it appears that nonveridical hypotheses are sources of interference, there appears to be no simple relation between the amount of interference created by these hypotheses and the length of time they have been held. Smock (1955) compared the visual recognition performance of a group of subjects under stress with the performance of a group of subjects who were more secure. He found that, over a series of five recognition problems, the difference between the mean recognition points for the two groups remained the same, with the stress group always recognizing later than the security group. What varied from problem to problem, however, were the differences between the (mean) points at which the two groups of subjects first formulated their hypotheses. On the basis of the lack of a systematic relation between the group means for these two variables, it would seem unlikely that recognition performance is a function of precocity of hypothesis formation.

If subjects differ in their susceptibility to the adverse effect of their own incorrect hypotheses upon subsequent formation of correct ones, then we might expect the individual differences in their recognition points to be reliable. While Bruner and Potter (1964) reported a Kendall measure of concordance (W) of only .116 for their 13 subjects, a reliability of .58 was obtained in another study using Bruner and Potter's pictures (Frederiksen, 1965), in spite of the fact that the pictures were deliberately chosen without recourse to an item analysis. Since individual differences in recognition performance were found to be moderately reliable, this study went on to examine the relations between perceptual recognition and five other cognitive and perceptual variables. While it was found that not all of the pictures required the same combination of abilities for their recognition, some general effects of the cognitive abilities on recognition were nevertheless discovered. The ability to visualize (to transform the image of a spatial pattern into other visual arrangements) was found to be associated with delayed recognition, while speed of closure (the ability to unify an apparently disparate perceptual field into a single percept) was related to early recognition. The post hoc explanation for the first of these results was that the ability to visualize contributes to late recognition because of the fact that visualizers can manipulate and transform their images of a stimulus and thereby make them conform to their hypotheses—albeit deceptively.

In addition to recognition-point measures, the subjects received scores which assessed their rates of hypothesis formation during the early stages of blur. When these scores were correlated with recognition points, it was found that the chances of recognizing a picture early were greater when a subject produced many initial hypotheses than when he was able to furnish only a few initial ideas ($r = -.46$). Subjects who could entertain many hypotheses simultaneously or in quick succession were presumably less susceptible to the interference which holding one hypothesis has on the formation of another. Similarly, subjects who advanced few hypotheses were, presumably, less able to develop new hypotheses to augment or replace their early ideas.

METHOD

The plan of the present study was (*a*) to develop a new recognition test which utilized a different sensory modality (audition) and which employed a previously untried technique for producing ambiguity, (*b*) to test the hypothesis that reducing the range of ambiguity would result in earlier recognition in both modalities than would be obtained using a wide range of ambiguity, (*c*) to find out if perceptual recognition performance in the two modalities is more highly correlated in the WRA group than in the NRA group, (*d*) to investigate the role played by a number of perceptual and cognitive factors in perceptual recognition, and in particular (*e*) to test the plausibility of the hypothesis that interference in perceptual recognition is related to a factor-analytically derived measure of flexibility (cognitive flexibility-rigidity). Since a number of different kinds of flexibility factors have been identified in the literature, this study had, as a sixth purpose, the factor-analytic investigation of the relations among a number of tests purporting to measure different aspects of cognitive flexibility.

Our interest in the problem of perceptual recognition concerns the psychological effects of hypothesis formation on the later revision of a hypothesis, once disconfirming evidence has become available. As the degree of stimulus ambiguity is gradually reduced, the number of possible interpretations of the stimulus diminishes, until, on the final trial, a single interpretation alone is tenable. By developing an analogous task in auditory recognition, it becomes possible to find out if general conclusions about the processing of ambiguous information can be reasonably drawn from the study of recognition in a single modality. With this purpose in mind, an auditory recognition test was devised in which single, polysyllabic words served as the objects to be recognized. Ambiguity was created by masking the words with a mixture of other speech sounds. When the signal-to-masking-noise ratio was low, the subject heard a variety of sounds which could be construed to represent any one of a number of possible words. As the masking noise was attenuated on successive trials, the probability of incorporating masking sounds into one's hypothesis grew smaller. Moreover, the masking sound associated with a word was identical through all successive presentations of the masked word, and only its loudness was altered. In this way, it was assured that the subject would continue to hear those elements of the masking sound which he had incorporated into his incorrect hypothesis. Since the loudness of these incorporated elements gradually diminished, the subject's incorrect hypotheses were not abruptly disconfirmed but, rather, grew steadily less plausible.

In order to assess the extent of interference in recognition, the subjects were divided into two groups which were given different versions of the two recognition tests. One group (the WRA group) was given versions of the auditory and visual recognition tests in which the full (wide) range of ambiguity was covered on each item. A second group (the NRA group), began each test item at a later stage of ambiguity than the normal starting point and thus received a reduced (narrow) range of ambiguity on every item. The subjects in the WRA group were thus given a greater opportunity to misinterpret the ambiguous stimuli than were the subjects in the NRA group, and it was hypothesized that the mean recognition points for the WRA group would exceed the means for the NRA group.

The principal similarity between the auditory and visual recognition tasks lies in the way prerecognition hypotheses were gradually made less plausible due to the slow reduction of stimulus ambiguity. Those abilities which are common to both recognition tasks should therefore be the ones which relate to interference in the successive formation of hypotheses as disconfirming evidence becomes available. Since there was greater opportunity for this interference to influence the recognition scores for the WRA group than for the NRA group, it was hypothesized that the auditory and visual recognition test scores would correlate more highly in the first group of subjects than in the second.

Cognitive Ability Measures

It has been suggested that a subject's performance in perceptual recognition is determined, in part, by his ability to reject promptly an erroneous hypothesis about the identity of the stimulus in favor of a new hypothesis when contradictory evidence becomes available. This concept of susceptibility to interference bears a striking resemblance to the notion of flexibility in problem solving. Flexibility has been characterized by Wand (1958) as "a sensitivity to changes in external conditions and an ability to adjust behavior to the uncertain or unexpected in problem situations [p. 3]." It is reflected in performance on tasks in which a habitual or set type of behavior results in a low score. In such tasks, the subject must reject routine or set problem-solving methods in favor of more efficient ones.

The selection of tests which purport to measure flexibility poses a problem due to the large number of such tests available and to the lack of knowledge about their interrelations (Chown, 1959). A number of investigations (Applezweig, 1954; Forster, Vinaake, & Digman, 1955; Goodstein, 1953; Wolpert, 1955) have failed to find significant correlations between selected measures of flexibility, and have raised doubts about the existence of a general flexibility factor. While a dispositional or cognitive rigidity factor has been found in at least two studies (Cattell & Tiner, 1949; Oliver & Ferguson, 1951), other studies by Scheier and Ferguson (1952) and Scheier (1954) have shown that most of the variance of the cognitive (and motor) rigidity tests could be accounted for by other, traditional ability factors such as motor speed, verbal reasoning, and number ability. In an attempt to see if all of the variance in flexibility tests could be explained in this way, Wand (1958) constructed a set of rigidity tests which were closely patterned after conventional tests of cognitive abilities. These experimental tests were designed so that the items, while resembling those of conventional aptitude tests, required the subject to "introduce new methods and to overcome sets [Wand, 1958, p. 29]." She tested the hypothesis that each of the flexibility tests had a significant portion of its non-error variance that was not correlated with the aptitude test on which it was patterned and found that most of the flexibility tests did indeed possess a significant amount of independent, non-error variance.

Since Wand's battery included tests representing a number of previously established flexibility factors (flexibility of closure, Guilford's adaptive flexibility—Frick, Guilford, Christensen, & Merrifield, 1959; Wilson, Guilford, Christensen, & Lewis, 1954—and Scheier and Ferguson's cognitive rigidity) along with her own experimental tests, it was felt that a further analysis of her data might reveal a group of tests that could serve, in the present study, as markers of flexibility. A factor analysis of the ability test portion of her data (her Variables 2 through 22) was therefore carried out, and five oblique factors were extracted. These factors were interpreted as (*a*) spatial ability, (*b*) cognitive flexibility-rigidity, (*c*) verbal ability, (*d*) numerical aptitude, and (*e*) speed of closure.

The cognitive flexibility-rigidity factor was clearly defined by Wand's experimental flexibility tests along with Scheier and Ferguson's Sign Changes and Reversed Reading tests. In addition, each of Wand's experimental tests was seen to load upon one of the conventional ability factors (spatial ability, verbal ability, or numerical aptitude) as was expected. The tests loading on cognitive flexibility-rigidity covered a variety of tasks, all of which required flexible thought. One of these tests, Verbal Problems, required the subject to ignore the contextual meanings of words; another, Resourceful Arithmetic, required the subject to reject routine methods of solving problems for more efficient and less habitual methods. The Sign Changes and Reversed Reading tests both required the subject to perform overlearned operations (reading and computing) in an unconventional manner. These tests, together with one experimental test of flexibility (Word Decoding), were included in the present test battery. The Word Decoding Test was thought to require flexible thought in that it tested how readily a subject could think up unusual pronunciations or meanings for letters and symbols.

Since Wand had used only two tests of flexibility of closure, it was impossible to obtain a separate factor representing this perceptual ability in the analysis of her data. Since it was felt that this "ability to overcome embeddedness [Witkin, 1964, p. 178]" might bear an interesting relationship to cognitive flexibility, as well as to visual and auditory recognition, several tests loading on this factor were included in the test battery. Two of these tests (Hidden Figures and Hidden Patterns) required the subject to search for and identify certain geometric forms which had been embedded in larger geometric figures. A third test (Copying) required the subject to copy angular geometric patterns onto a square matrix of dots. It was expected that flexibility of closure and cognitive flexibility-rigidity would form distinct, but highly oblique factors.

Tests representing a third flexibility factor, semantic spontaneous flexibility (identified by Frick et al., 1959; Wilson et al., 1954), were included as well. This factor has been defined by French, Ekstrom, and Price (1963) as "the ability to produce a diversity of verbally expressed ideas in a situation that is relatively unrestricted [p. 50]." The two representative tests, Utilities and Object Naming, were scored for the number of shifts in categories of responding which a subject makes in listing the utilities or names of objects. Several measures of ideational fluency [3] were also included, in order to control for the tendency of some subjects to produce more answers than others in an open-ended test. It was expected that the tests of semantic spontaneous flexibility would load highly on this fluency factor.

In addition to our three measures of flexibility, tests representing four perceptual abilities were selected from the set of factor tests reviewed and described by French et al. (1963), and were included in the present study. The first of these factors, visualization, has been defined as "the ability to manipulate or transform the image of spatial patterns into other visual arrangements [French et al., 1963, p. 47]." It was measured by tasks which required

[3] Ideational fluency was represented by two published tests (Topics and Thing Categories) and two tests prepared especially for this study (Sound Interpretation and Interpreting Inkblots). In the Sound Interpretation Test, the subject listened to two 50-second recorded selections, which contained a mixture of sound effects, and was asked to write down what the selections sounded like.

the subject to "imagine" how an object would appear after it had been moved through space in some complex series of specified motions; he then had to select from a set of alternatives the figure having the appearance of the transformed object. The three tests of this factor (Form Board, Paper Folding, and Surface Development) were administered under relatively unspeeded conditions. It was expected that visualization would be related to visual recognition when a broad range of ambiguity was employed, as it was in the previous study.

Since tests of visualization resemble tests of spatial orientation, measures of this second spatial factor were included in order to insure that an unambiguous measure of visualization would be obtained. The two spatial orientation tests (Card Rotations, Cube Comparisons) evaluated the subject's perception of the positions of objects in relation to his own position as the observer. The test items were relatively easy and were given under highly speeded conditions.

The third perceptual factor represented was speed of closure; it was assessed by means of tests which required the subject to identify incomplete figures or words (the Concealed Words and Gestalt Completion tests). In the previous study speed of closure was found to be associated with early slide recognition. However, since this ability involves tasks in which a perceptual field containing disparate parts is viewed, it would appear likely that speed of closure would be more highly related to visual recognition for subjects who began viewing the ambiguous pictures at a point where the visual field was more differentiated, that is, for subjects in the NRA group.

A spatial speed factor, spatial scanning, was also represented in the test battery. The three tests of spatial scanning (Maze Tracing, Choosing a Path, Map Planning) measured the subject's speed in surveying a complicated spatial field and were administered under highly speeded conditions. Finally, a memory factor (memory span) was represented in the test battery. The two measures of this factor were conventional letter- and number-span tests (Kelley, 1954), in which series of letters or digits of varying lengths were read to subjects, who then had to reproduce them immediately. This factor was included in the study because it was thought that rapid memorization of the sounds contained in the auditory recognition test might perhaps facilitate early recognition of the stimulus word.

The Visual Recognition Task

The visual recognition test consisted of a series of 14 color slides containing pictures of ordinary objects. Subjects were shown each of these pictures in a sequence of 15 stages of decreasing ambiguity. The ambiguity was produced by a blurring of the pictures, which reduced the amount of detail observable in the objects photographed and distorted their appearance. Thus each of the slides was presented in 15 different stages of gradually improving focus, covering 14 subjectively equal focus intervals (Frederiksen, 1965). The subjects were asked to try to identify these pictures as they came into focus. The slides were projected using a Kodak Carousel projector onto a standard $4\frac{1}{2} \times 6$-foot grainless screen. At each stage of focus, a picture was exposed for 10 seconds, followed by a 10-second pause during which the subjects wrote their guesses about what the slide depicted. In all, 5 minutes were spent on each picture.

A subject's recognition point was defined as the stage of focus at which a criterion word or phrase (distinct for each slide) was first mentioned without a subsequent return to an incorrect hypothesis. If a subject failed to write down the criterion word, he was given a score of 16. The scores therefore ranged from 1 (immediate recognition on the first and most blurred trial) to 15 (recognition at full focus) and then 16 (no recognition at all). A more complete description of the visual recognition test and the methods used in its construction was given in a previous report (Frederiksen, 1965).

The Auditory Recognition Task

Having decided to use a masking technique to create ambiguity for the test of auditory recognition, and having settled on the use of single, polysyllabic words for items to be recognized, the authors turned to the study of Blake and Vanderplas (1950) for a source of such words. From their list of 84 words, the 20 words having the largest numbers of prerecognition hypotheses were selected. Each of these had at least 8 prerecognition hypotheses, the highest number being 14. The auditory recognition test was then constructed out of these 20 items by masking each of them with other speech sounds.

The auditory masking was accomplished in the following manner: A master tape was prepared containing on a single track four voices of approximately equal loudness, all belonging to the same speaker, and all speaking at once. On the second track of this tape were recorded the stimulus words, each one thus being accompanied by its own particular masking sound. This tape could be played back any number of times, in order to combine stimulus words and masking ones in any desired proportions of loudness. In this way, each test item was recorded 15 times, with the identical masking sound accompanying each recording. The only difference between successive recordings of the stimulus-mask composite was the degree of attenuation of the masking signal. On the first trial, stimulus and mask were equally loud, while on subsequent trials, the loudness of the masking sound was attenuated, 1 decibel for each trial. The scale of ambiguity for the auditory recognition test ran from no attenuation on Trial 1, to 14 decibels attenuation on Trial 15.

The item analysis. Twenty subjects, who were college students and summer employees of the Educational Testing Service, took the 20-item auditory recognition test. After each presentation of the stimulus word, a 5-second pause was provided, during which the subjects wrote their guesses about the identity of the word. The auditory items were presented to groups of five subjects in one of four different orders: the items were divided into quarters containing five items, and each group of items was presented once as the first, second, third, and last group to be heard by a group of subjects.

The scoring procedures resembled those used for scoring the visual recognition test. A subject's recognition point was defined as the first trial on which he first heard the correct word without returning to an incorrect hypothesis about the word. If a subject failed to write down the criterion word at all, he was given a score of 16. For the most part, the scoring criteria were furnished by the item words themselves. However, the criteria for two of the items were rendered "easier": by allowing the inclusion of the suffixes -ed or -ing.

The odd-even reliability of the average recognition score in this preliminary study was .78 (corrected for double length), despite the fact that the item order was not fixed for all 20 subjects. However, four items which correlated either zero or negatively with the total score were eliminated from the final form of the test.

The experimental design permitted an assessment of the extent to which subjects improve with practice in recognizing masked words. While the degree of improvement in recognition appeared to be linearly related to the amount of practice on the test, none of the differences between mean recognition trials for the four quarters of the test were statistically significant. In the revised form of the auditory test, the order of the items was altered: difficult items were placed near the end of the test, while easy items were offered at the beginning. In this way, use was made of whatever systematic relation existed between an item's recognizability and its position in the test. The items in the revised form of the test were in a fixed order. Detailed item statistics have been presented elsewhere (Frederiksen, 1966).

Subjects

The subjects for this study were 145 male college undergraduate and graduate students at Princeton University. All of the subjects were paid volunteers, solicited by mail or poster. The WRA group, consisting of 85 subjects, was run in December, after classes had recessed prior to Christmas vacation. The NRA group, containing 60 subjects, was run in February, during the first week of the spring semester.

Experimental Procedure

The 29 cognitive tests were administered to both groups of subjects. They were given in two sessions, each lasting from 3 to $3\frac{1}{2}$ hours. The tests were hypothesized to represent the cognitive factors listed in Table 3 where footnote *a* indicates those tests which were thought to load on each factor. The order of presentation was arranged so that two tests measuring the same ability were never contiguous; moreover, the kinds of tasks required of a subject were varied during any given time period. In addition, an effort was made to separate the more lengthy tests from each other. Although the order of administration of the tests was fixed within each session, subjects were allowed to attend an evening session, prior to taking part in an afternoon session.

The auditory and visual recognition tests were given in the afternoon and evening sessions, respectively. In constructing the versions of the recognition tests given to the NRA group, it was intended that the reduction in the number of stages of ambiguity should be sufficient to produce a decrease in the number of early, "interference-creating" hypotheses. At the same time, however, it was necessary to avoid a restriction in the range of recognition scores possible, due to the elimination of trials on which subjects might have recognized an item. The following criterion was therefore adopted: For every auditory and visual item, all trials (stages of ambiguity) were eliminated on which the cumulative percentage of subjects who recognized the item was less than 4%. In those cases, however, where fewer than a third of the trials were eliminated using this rule, a criterion of 8% was used instead. The number of stages of ambiguity deleted was therefore determined for each item from the distribution of recognition points on that item. From the auditory test, as few as 3 and as many as 8 stages of ambiguity were eliminated, and from the visual test, as few as 3 and as many as 10 focus stages were eliminated. The average number of trials eliminated was 5.9 for the auditory test and 6.6 for the visual recognition test.

Scoring Procedure

The auditory and visual recognition tests were scored according to the method described above. Since the scoring criteria were applied literally, it was not deemed necessary to assess the reliability of the scoring. The scorers, of course, were kept naive about the purpose of the study and were therefore unaware of the hypothesis that subjects in the NRA group were expected to recognize the auditory and visual items earlier than subjects in the WRA group.

The subjects' scores on the cognitive ability tests were for the most part simply the numbers of items correctly completed, and no corrections for guessing were made. The keys for scoring most of the tests are given in French et al. (1963); the keys for scoring the tests of flexibility-rigidity were developed for this study by the author. The tests of ideational fluency were scored for the number of different answers written in the time period allowed, and no attempt was made to assess the quality of the answers. The two tests of semantic spontaneous flexibility were scored for the number of shifts from one category of responding to another (French et al., 1963).

RESULTS

It was hypothesized that a reduction in the range of ambiguity covered in the presentation of auditory and visual items should result in earlier recognition of the items. Those subjects exposed to a wide range of ambiguity were expected to recognize items later than were those subjects who had escaped the early, and highly ambiguous trials. This hypothesis was strongly confirmed for both modalities.

Auditory Recognition

The distributions of recognition points for a typical auditory item, for both groups of subjects, are shown in Figures 1 and 2. In Figure 1, it can be seen that nearly 60% of the subjects scored 16 (i.e., failed to recognize the item at all) when the full range of ambiguity was covered. Of the subjects who did recognize, the earliest did so on Trial 5. On the other hand, in Figure 2 we see that 60% of the NRA group—the group first hearing the stimulus word on what was originally the eighth trial—recognized the word "beauty" *immediately*. Only 15% of the subjects in the NRA group remained completely unable to recognize this word. This finding was typical of the auditory items; reducing the range of ambiguity produced a complete change in the shape of the distributions of recognition points. Whereas large proportions of the subjects in the WRA group were unable to recognize the words at all, subjects in the NRA group often recognized the words immediately. At the same time, the distributions of recognition points for those subjects who did *not* recognize on the first trial were

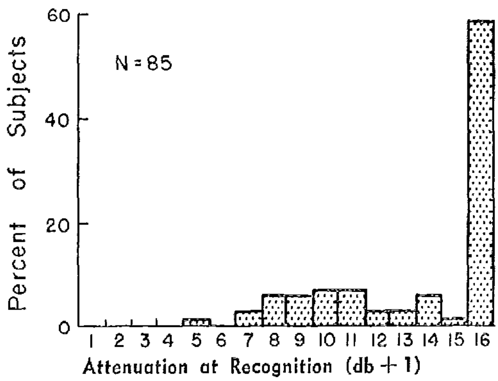

FIG. 1. The distribution of recognition points for the auditory item "beauty" obtained when the full range of ambiguity was covered.

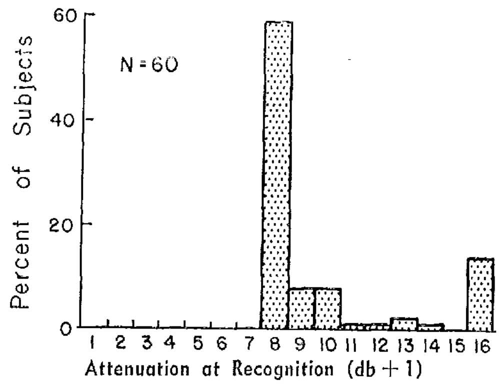

FIG. 2. The distribution of recognition points for the auditory item "beauty' obtained when the first seven stages of ambiguity were omitted.

the same for both groups. This implies that the length of time a hypothesis has been held is not an important factor.

While there were differences in amount of interference for different items, all of the items nevertheless had smaller mean recognition points when the range of ambiguity was reduced. The amount of interference (that is, the difference between median recognition trials for the two groups) associated with an item correlated significantly ($r = .53$) with the number of distinct prerecognition hypotheses obtained for that item in the study of Blake and Vanderplas (1950).

Disregarding item differences, the mean score for the WRA group on the entire test was 12.08, ($SD = 1.47$) while the mean for the NRA group was only 9.74 ($SD = 1.13$). The critical ratio for the difference between the *corrected* mean recognition point[4] for the WRA group and the mean for the NRA group was over 15 ($p < .001$). The odd-even reliability (corrected for double length) of the original version of the test was .80, while it was .52 for the reduced range version.

Visual Recognition

The distributions of recognition points for a typical visual item are given in Figures 3 and 4. The distribution for the WRA group is skewed to the left, while that for the NRA

[4] Corrected mean recognition points for the WRA group were computed in the usual way from subjects' item recognition points, except that if a subject's item score fell below the starting trial for the NRA group, it was raised to that value.

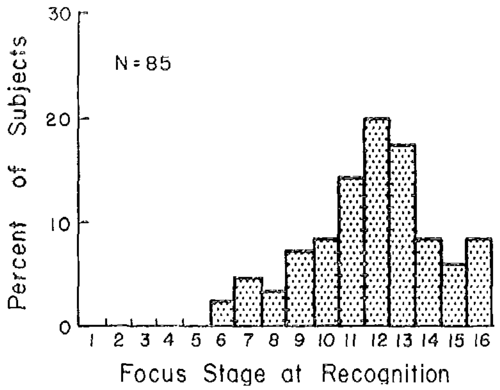

FIG. 3. The distribution of recognition points for the visual item "shoes" obtained when the full range of ambiguity was covered.

group (which began viewing on the seventh stage of focus) is skewed to the right. Unlike those for the auditory items, not all of the mean recognition scores for the visual items decreased when the overall range of ambiguity was reduced. However, the mean recognition points decreased for all but three of the pictures.

Comparing the total scores on the visual recognition test, the mean recognition point for the WRA group was 11.54 ($SD = 1.06$), while the mean score for the NRA group was 10.73 ($SD = 1.00$). The critical ratio for the difference between the *corrected* mean for the WRA group and the mean for the NRA group was 5.12 ($p < .001$). Thus, despite the fact that less overall time was provided for subjects in the NRA group to view the ambiguous stimuli, they recognized the items earlier

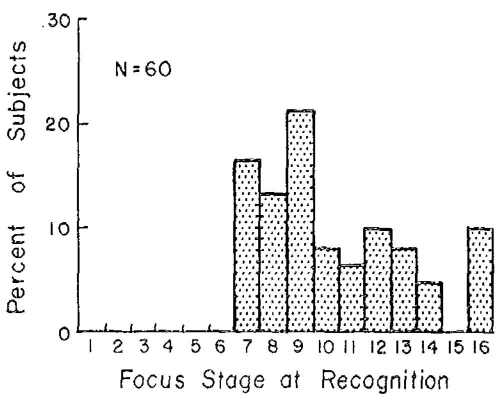

FIG. 4. The distribution of recognition points for the visual item "shoes" obtained when the first six stages of ambiguity were omitted.

than did subjects in the WRA group. The reliability of the test was essentially the same for both groups (.68 in the WRA group and .72 in the NRA group).

The effect of decreasing the range of ambiguity on recognition has been attributed to

TABLE 1

DESCRIPTIVE STATISTICS OF THE COGNITIVE TESTS

Cognitive test	Group I		Group II		Reliability[b]
	M	*SD*	*M*	*SD*	
1. Concealed words	25.92	5.39	24.62	4.87	.75
2. Gestalt completion	17.09	3.24	17.50	2.91	.77
3. Form board	23.12	8.08	21.70	8.79	.81
4. Paper folding	15.34	3.16	14.57	3.98	.86
5. Surface development	49.96	11.24	48.35	10.30	.88
6. Sound interpretation	19.40	8.81	18.53	8.71	.82
7. Interpreting inkblots	13.32	5.80	11.97	5.54	.85
8. Topics	29.56	10.58	33.20	13.24	.90
9. Thing categories	31.87	8.72	33.37	11.57	.67
10. Hidden figures	18.27	7.48	16.28	6.41	.76
11. Hidden patterns	184.49	28.37	178.60	30.61	.91
12. Copying	39.89	11.03	41.47	9.32	.89
13. Card rotations	169.18	35.76	171.35	30.96	.85
14. Cube comparisons	29.84	7.01	29.02	7.18	.77
15. Sign changes	46.35	6.98	44.98	6.48	.85
16. Reversed reading	23.66	6.78	20.47	5.74	.94
17. Resourceful arithmetic	26.12	8.08	23.25	7.51	.86
18. Verbal problems	22.92	6.36	22.45	5.98	.72
19. Utilities[a]	20.14	7.20	18.90	7.88	.74
20. Object naming[a]	11.56	3.62	12.40	3.46	.40
21. Word decoding	18.66	5.62	16.95	5.02	.67
22. Advanced vocabulary	29.40	4.93	27.75	4.21	.83
23. Maze tracing	27.82	6.58	28.67	7.32	.92
24. Choosing a path	16.79	5.70	16.52	6.03	.78
25. Map planning	25.78	5.73	25.02	7.11	.75
26. Auditory number span	11.64	3.41	12.22	3.94	.80
27. Auditory letter span	10.95	3.19	10.50	3.11	.73

[a] Scored for the number of shifts between categories of response.
[b] Corrected for double length.

the interference of erroneous, prerecognition hypotheses with the later formation of correct hypotheses when additional information about the stimulus becomes available. If this is the case, then individual differences in susceptibility to interference should determine in part how poorly subjects will perform. Since interference-producing hypotheses were presumably less likely in the NRA group, the auditory and visual and recognition scores should be more highly (positively) correlated in the WRA group than in the NRA group. The correlation between average recognition points on the two tests was .18 (corrected for attenuation) for the WRA group, and the correlation for the NRA group was −.03 (again, corrected for attenuation). Neither of these correlations was, however, statistically significant.

Factor Analysis

Descriptive statistics of the cognitive tests are given in Table 1. Three of the tests had reliabilities below .75 (Thing Categories, Object Naming, and Word Decoding). The Object Naming Test had the lowest reliability (.40), and this may have been due to scoring errors, as this test was scored for the number of shifts between categories of responding. The means and standard deviations of the tests were computed separately for each group. Although none of the differences between these means and standard deviations are statistically significant, separate variance-covariance matrices were nonetheless computed for each group, and it was the weighted average of these two matrices that was factored. This average variance-covariance matrix, rescaled so as to have unities in its principal diagonal, is given in Table 2. Since the maximum likelihood method of factor analysis involves the assumption that the test scores are distributed according to the multivariate normal distribution, separate chi-square tests of normality were computed for each of the cognitive tests. Using the .01 significance level, seven of the cognitive tests were judged not to be normally distributed. Three of these tests (Gestalt Completion, Surface Development, and Advanced Vocabulary) had skewed distributions which indicated that they were not sufficiently difficult to discriminate optimally among the students tested. Since the normality assumptions were not met, the significance test computed in the factor analysis was disregarded.

The average of the group variance-covariance matrices was factored according to the method of Jöreskog (1966), using his iterative program for the IBM 7094 computer. In the Jöreskog factoring procedure, the indeterminacy of the factor model is eliminated by reducing the number of parameters contained in the factor matrix. This is accomplished by setting certain factor loadings exactly equal to zero. The set of the zero loadings constitutes the experimenter's simple structure hypothesis.

The factor loadings which were originally thought to be nonzero are indicated by footnote *a* in Table 3. After factoring the correlation matrix for the WRA group, this simple structure hypothesis was revised, and several additional factor loadings were postulated. The final simple structure hypothesis is indicated by the positions of zeroes in Table 3. Using this simple structure hypothesis the average variance-covariance matrix was factored, yielding a normal deviate of −3.23, which suggested that an excellent approximation to the combined data for the two groups had been achieved. The final estimates of the factor matrix, the uniqueness of the tests, and the average factor variance-covariance matrix are given in Tables 3 and 4. The factor loadings can be interpreted as regression weights for the regression of each test on the 10 factors.

Five perceptual factors. Thirteen tests involving five different aspects of visual perception were included in the test battery. The factor "speed of closure" was best represented by the Concealed Words Test which loaded on no other factors. The Gestalt Completion Test loaded appreciably on visualization (.40) and cognitive flexibility (−.41), as well as loading .46 on the factor it was intended to represent.

The tests designed to measure visualization all loaded greater than .89 on that factor, and only slightly on other factors. However, there was a large covariance (.80) between visualization and spatial orientation which indicated that an alternative solution would have been

TABLE 2

WEIGHTED AVERAGE OF THE GROUP DISPERSION MATRICES RESCALED SO AS TO HAVE UNITIES IN THE PRINCIPAL DIAGONAL[a]

Cognitive test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1. Concealed words	100																										
2. Gestalt completion	26	100																									
3. Form board	29	40	100																								
4. Paper folding	20	43	67	100																							
5. Surface development	19	41	68	66	100																						
6. Sound interpretation	−8	6	13	9	4	100																					
7. Interpreting inkblots	−4	2	22	18	16	55	100																				
8. Topics	7	−2	20	11	6	46	35	100																			
9. Thing categories	7	8	26	19	19	25	34	41	100																		
10. Hidden figures	25	14	38	41	47	6	18	16	25	100																	
11. Hidden patterns	27	21	34	30	40	−9	−4	13	27	50	100																
12. Copying	32	20	55	51	50	1	12	16	33	52	57	100															
13. Card rotations	19	28	53	42	52	7	7	13	36	36	40	54	100														
14. Cube comparisons	18	20	52	48	50	8	7	9	21	29	30	44	51	100													
15. Sign changes	26	−8	2	3	−1	−5	−5	7	21	34	36	24	17	24	100												
16. Reversed reading	36	0	13	17	14	−15	−10	12	26	43	35	32	27	36	47	100											
17. Resourceful arithmetic	19	−0	24	39	29	3	9	12	31	27	34	45	37	41	53	41	100										
18. Verbal problems	26	31	28	36	27	2	9	17	28	29	29	34	25	29	31	51	37	100									
19. Utilities	−6	8	21	13	17	37	38	56	47	10	7	16	19	19	−6	7	−0	22	100								
20. Object naming	−6	18	12	12	15	15	23	18	25	14	13	9	4	14	2	11	5	23	35	100							
21. Word decoding	25	17	13	16	20	−4	3	10	21	20	13	16	21	16	16	59	23	55	19	16	100						
22. Advanced vocabulary	−6	7	10	6	1	8	16	20	17	6	−2	10	−6	4	1	27	7	38	25	15	39	100					
23. Maze tracing	10	18	34	31	35	17	18	16	28	42	42	46	39	21	7	18	18	23	23	16	8	8	100				
24. Choosing a path	15	21	47	59	55	22	26	14	18	39	27	46	44	40	9	11	37	24	22	8	8	1	39	100			
25. Map planning	20	10	34	35	27	13	15	24	29	41	38	43	47	37	28	32	41	26	24	13	19	−2	48	40	100		
26. Auditory number span	11	−2	0	7	4	−12	−3	−7	−3	16	10	12	−7	10	38	35	33	25	−6	6	21	11	−7	4	20	100	
27. Auditory letter span	11	−5	−0	4	8	−3	−1	4	10	19	13	15	8	11	32	33	33	28	4	−3	22	23	−2	9	21	68	100

[a] Decimal points have been omitted.

TABLE 3

MAXIMUM LIKELIHOOD ESTIMATES OF FACTOR LOADINGS AND UNIQUENESSES

Cognitive test	1 Speed of closure	2 Visualization	3 Ideational fluency	4 Flexibility of closure	5 Spatial orientation	6 Cognitive flexibility rigidity	7 Semantic spontaneous flexibility	8 Verbal ability	9 Spatial scanning	10 Memory span	Uniqueness
1. Concealed words	0.65[a]	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.58
2. Gestalt completion	0.46[a]	0.40	0.	0.	0.	−0.41	0.	0.	0.	0.	0.60
3. Form board	0.	0.89[a]	0.	0.	−0.08	0.	0.	0.	0.	0.	0.31
4. Paper folding	0.	0.93[a]	0.	0.	−0.20	0.09	0.	0.	0.	0.	0.35
5. Surface development	0.	0.90[a]	0.	0.	−0.09[a]	0.	0.	0.	0.	0.	0.31
6. Sound interpretation	0.	0.	0.71[a]	0.	0.	0.	0.	0.	0.	0.	0.50
7. Interpreting inkblots	0.	0.	0.65[a]	0.	0.	0.	0.	0.	0.	0.	0.57
8. Topics	0.	0.	0.67[a]	0.	0.	0.14	0.	0.17	0.	0.	0.51
9. Thing categories	0.	0.	0.67[a]	0.13	0.	0.27	0.36	0.01	0.	0.	0.57
10. Hidden figures	0.	0.	0.	0.66[a]	0.	0.	0.	0.	0.04	0.	0.52
11. Hidden patterns	0.	0.	0.	0.70[a]	0.	0.	0.	0.	0.	0.	0.51
12. Copying	0.	0.	0.	0.73[a]	0.	0.	0.	0.	0.09	0.	0.36
13. Card rotations	0.	0.	0.	0.09[a]	0.42[a]	0.	0.	0.	0.35	0.	0.46
14. Cube comparisons	0.	0.	0.	0.	0.80[a]	0.	0.	0.	0.	0.	0.36
15. Sign changes	0.	0.	0.	0.	0.	0.73[a]	0.	0.	0.	0.	0.47
16. Reversed reading	0.	0.	0.	0.	0.	0.63[a]	0.	0.49[a]	0.	0.	0.32
17. Resourceful arithmetic	0.	0.	0.	0.	0.	0.69[a]	0.	0.	0.	0.	0.52
18. Verbal problems	0.	0.	0.	0.	0.	0.37[a]	0.	0.60[a]	0.	−0.00[a]	0.48
19. Utilities	0.	0.	1.04[a]	0.	0.	0.04[a]	0.72[a]	0.	0.	0.	0.28
20. Object naming	0.	0.	0.50[a]	0.	0.	0.07[a]	0.43[a]	0.	0.	0.	0.81
21. Word decoding	0.	0.	0.	0.	0.	0.22[a]	0.	0.76[a]	0.	0.	0.35
22. Advanced vocabulary	0.	0.	0.	0.	0.	0.	0.	0.52[a]	0.	0.	0.73
23. Maze tracing	0.	0.	0.	0.	0.	0.	0.	0.	0.71[a]	0.	0.49
24. Choosing a path	0.	0.47	0.	0.	−0.00	0.	0.	0.	0.27[a]	0.	0.55
25. Map planning	0.	0.	0.	0.	0.	0.	0.	0.	0.71[a]	0.32	0.45
26. Auditory number span	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.91[a]	0.18
27. Auditory letter span	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.75[a]	0.43

[a] Loadings which were hypothesized prior to the factor analysis.

to combine these two factors into a single, spatial factor. The failure to clearly differentiate between visualization and spatial orientation in this analysis was undoubtedly due to the fact that only two tests of spatial orientation were included in the test battery.

The spatial scanning factor has been interpreted as a spatial speed factor (French et al., 1963). Since the Card Rotations Test was more highly speeded than the Cube Comparisons Test, its loading of .35 on the speed factor was not unreasonable. Spatial scanning seemed to correlate with the other factors in proportion to the degree to which the tests of the other factors were speeded. Thus it covaried most highly with flexibility of closure, visualization, and spatial orientation, and only slightly with verbal ability, semantic spontaneous flexibility, and memory span.

The Hidden Figures, Hidden Patterns, and Copying tests together determined a factor which was labeled "flexibility of closure" after French et al. (1963) and which has been termed "field dependence-independence" by Witkin (1964). Since these tests loaded only on flexibility of closure, their covariance with other tests in the battery were almost entirely accounted for by the interfactor covariances. In Table 4 we see that flexibility of closure was highly related to the other four perceptual factors.

Flexibility factors. The factor analysis was designed to investigate the relations among groups of tests which purport to measure several different kinds of flexibility in thinking. One such group included two tests which required subjects to perform overlearned operations, such as reading and computing, in an unusual manner (Scheier, 1954; Scheier & Ferguson, 1952). Another test in this group required them to reject routine methods of solving problems in arithmetic for more efficient methods (Wand, 1958). In a fourth test, subjects had to ignore the contextual meanings of words (Wand, 1958). These four tests together determined the factor named

TABLE 4

MAXIMUM LIKELIHOOD ESTIMATE OF THE FACTOR VARIANCE-COVARIANCE MATRIX[a]

Factor	1	2	3	4	5	6	7	8	9	10
1. Speed of closure	100									
2. Visualization	41	100								
3. Ideational fluency	−14	19	100							
4. Flexibility of closure	59	71	6	100						
5. Spatial orientation	37	80	7	60	100					
6. Cognitive flexibility-rigidity	−54	25	−8	66	54	100				
7. Semantic spontaneous flexibility	5	2	−58	8	17	−4	100			
8. Verbal ability	36	21	−0	16	15	6	47	100		
9. Spatial scanning	27	56	35	71	48	34	−6	9	100	
10. Memory span	25	5	−16	21	13	52	12	18	−11	100

[a] Decimal points have been omitted.

"cognitive flexibility-rigidity," as in the previous factor analysis of data obtained by Wand.

In another pair of tests, subjects received high scores only if, in listing utilities or names of objects, their categories of response constantly changed. This pair of tests determined a factor termed "semantic spontaneous flexibility" (Frick, et al., 1959; French et al., 1963). Neither of these tests loaded on cognitive flexibility-rigidity.

Tests representing two "control" factors were included in the battery of tests; these factors were ideational fluency and verbal ability. In Table 3, it can be seen that the tests of semantic spontaneous flexibility loaded highly on ideational fluency and that two of the tests of cognitive flexibility loaded on the verbal factor. In addition, the experimental test "Word Decoding" loaded to a higher degree on the verbal factor (.76) than it did on the cognitive flexibility factor (.22). With the single exception of the Word Decoding Test, the factor loadings of the flexibility tests confirmed our hypothesis concerning the relations among the various measures of "flexibility."

TABLE 5

A COMPARISON OF THE REGRESSION B WEIGHTS AS A FUNCTION OF THE RANGE OF AMBIGUITY WITHIN EACH MODALITY

Cognitive factor	Auditory recognition		Visual recognition	
	WRA group	NRA group	WRA group	NRA group
1. Speed of closure	− .69	.61	− .35	−1.54
2. Visualization	− .72	− .44	−1.85	1.04
3. Ideational fluency	− .37	.28	.85	− .11
4. Flexibility of closure	2.52	1.24	2.67	− .81
5. Spatial orientation	.75	.75	.94	−1.66
6. Cognitive flexibility-rigidity	−1.23	−1.35	− .68	2.34
7. Semantic spontaneous flexibility	− .59	− .06	.45	− .41
8. Verbal ability	.35	−1.47	− .38	1.23
9. Spatial scanning	−2.07	− .34	−1.90	.12
10. Memory span	− .00	.32	.28	− .35
Multiple correlation	.36	.76	.51	.77

Observing the inter-factor covariances it can be seen that two of the flexibility factors (flexibility of closure and cognitive flexibility-rigidity) were highly related, having a covariance of .66. The covariances of these two factors with the third flexibility factor (semantic spontaneous flexibility) were only .08 and −.04, respectively. Furthermore, flexibility of closure and cognitive flexibility-rigidity were essentially uncorrelated with either ideational fluency or verbal ability; these covariances were all .16 or less. On the other hand, semantic spontaneous flexibility covaried with both verbal ability (.47) and ideational fluency (−.58), the later covariance probably resulting from the method of scoring which tended to penalize students who wrote many responses belonging to a single category.

Two tests of auditory memory span were included, in order to see if memory was an important factor in successful performance on the auditory recognition test. Memory span was strongly related to only one of the other factors, that being cognitive flexibility-rigidity, with which it had a covariance of .52.

Predicting Recognition from the Cognitive Factors

In order to compute the regression equations for predicting auditory and visual recognition from the cognitive factors for the two groups of subjects, it was necessary to obtain separate estimates of the factor variances and covariances for the two groups. These were obtainable from the covariances between the recognition tests (the criterion variables) and the factor tests, provided the assumption was tenable that the recognition tests were uncorrelated with uniqueness in any of the factor tests. Using the procedure described in a previous report (Frederiksen, 1966) least-squares estimates of the criterion-factor covariances were obtained, using all of the cognitive tests in the estimation equation. Upon checking the assumption about the lack of correlation between criterion and uniqueness, it was discovered that uniqueness in several of the tests correlated with the recognition tests. These tests were eliminated in the computation of a second set of approximations to the criterion-factor covariances, and it was this second set of covariances that was used in computing the regression weights which are given in Table 5.

Both recognition tests were more amenable to prediction under the conditions of reduced range of ambiguity than under conditions of full range of ambiguity. For the WRA group, the obtained multiple correlations were .36 for auditory and .51 for visual recognition; of the two, only the multiple R for predicting visual recognition was significant at the .05 level. On the other hand, the multiple Rs for the NRA group were both significant at better than the .001 level; they were .76 for auditory and .77 for visual recognition. The hypothesis that the standard errors of estimate for the two treatment groups were equal (Gulliksen & Wilks, 1950) was rejected at better than the .01 level of significance. It is clear, then, that one effect of reducing the range of ambiguity was to render the recognition tests more predictable from the factor scores. The regression B weights are given in Table 5; these are the weights which take into account the common scale used to express recognition points in the two groups. A negative weight for an ability factor means that subjects with high ability tend to recognize earlier than those with low ability.

On the basis of the previous study (Frederiksen, 1965), it was hypothesized that visualization would be positively related to visual recognition in the WRA group, but not in the NRA group, and that speed of closure would be more negatively related to visual recognition in the NRA group than it would in the WRA group. An inspection of the regression weights revealed the following: (*a*) High visualization ability was associated with early visual recognition in the WRA group and with late recognition in the NRA group; (*b*) high spatial scanning ability was associated with early visual and auditory recognition in the WRA group; (*c*) high speed of closure was related to early visual recognition in the NRA group, while it was unrelated to auditory recognition in either group.

The previous finding of a positive relationship between visualization and late visual recognition in the WRA group was not replicated. Instead, the factor "spatial orientation" (originally included in the analysis in order to ensure that the visualization factor would not be confounded with this ability) was related to visual recognition in the same manner as was visualization in the previous study; it was associated with late recognition of visual items when a wide range of ambiguity was covered. Since spatial orientation and visualization were more highly correlated in the present study than in the previous one, it is possible that the previous findings may have been due in part to a confounding of these two abilities.

In addition to the above hypotheses, the author wanted to find out whether cognitive-flexibility-rigidity would be negatively related to auditory and visual recognition in the WRA group, and whether memory span would be negatively related to auditory recognition in both groups. It was found that (*d*) high cognitive flexibility was indeed associated with early recognition of auditory stimuli in the WRA group, and in the NRA group as well.

It was, however, related to *late* recognition of visual stimuli when the range of ambiguity was narrow; (*e*) memory span was unrelated to either auditory or visual recognition.

Although no hypotheses were made regarding the role of flexibility of closure in perceptual recognition, inspection of Table 5 reveals that this factor was associated with late recognition of auditory items in both groups and with late visual recognition in the WRA group. On the other hand, another type of flexibility—"that of semantic spontaneous flexibility"—was unrelated to recognition performance in either modality.

Verbal ability was included in the analysis primarily to serve as a control variable, for the purpose of purifying the measurement of cognitive flexibility-rigidity. However, it also predicted recognition performance in the NRA group, where it predicted both auditory and visual recognition.

Discussion

Interference in Perceptual Recognition

The adverse effect of an initial exposure to an ambiguous stimulus upon perceptual recognition has been demonstrated in two modalities. This effect was especially striking when auditory stimuli were employed. While the average percentage of words which were eventually recognized by subjects in the NRA group was 82%, subjects in the WRA group were able finally to recognize an average of only 53% of the words. In contrast, the comparable percentages for visual recognition were 88% and 84%, respectively, for the NRA and WRA groups. A possible explanation for the greater amount of interference in auditory, as compared to visual, recognition lies in the dissimilarity between the methods used to create ambiguity in the two cases.

In the visual recognition task, ambiguity was produced by blurring the pictures, so as to produce a loss of visual detail. In attempting to recognize such pictures, subjects feel hard pressed to come forth with specific interpretations, and instead develop hypotheses which are both tentative and vague. Their initial impressions may take the form of assumptions about the composition of each picture; they seldom involve explicit hypotheses about the identity of the stimulus. For example, in viewing "ashtrays piled up," a subject might have the impression that the blurred white objects are opaque, when in reality they are transparent. The subject who sees them as opaque might later on venture specific hypotheses, such as "crackers," "newspapers," or "magazines," thus failing to take into account the transparency of the objects pictured. Such an initial impression or "constraint set" (Davison, 1964) is dependent upon particular characteristics of a given picture, as well as upon the stage of focus at which the picture is first presented. There are consequently large differences among the pictures in their distributions of recognition points.

In the auditory recognition task, on the other hand, a subject who listens to *any* highly masked stimulus can discern specific words which are embedded in the masking background. These words are clearest when the masking sounds are at their loudest, and they provide a defensible solution to the recognition problem at that point. The subject has no reason to believe his hypothesis erroneous until he discovers that the loudness of the sounds which he has incorporated into that hypothesis is diminishing. However, since the changes in masking loudness occurring on each trial are small (1 decibel), this loudness discrimination is difficult to make, and it is only with careful attention to loudness changes over a series of trials that it becomes possible to identify those sounds whose loudness is actually decreasing. The problem is further complicated for the subject who has formed a hypothesis about the organization of the perceptual field: his capacity to judge changes in loudness has been biased in that those elements of the auditory stimulus which have become salient to him seem to have constant loudness, when in fact their loudness is diminishing. Since this biasing of a subject's judgment can in principle occur with any of the items, the greater uniformity among the distributions of recognition points for the auditory items, as compared with those for the visual ones, was to be expected.

There is additional evidence, in the form of a significant correlation ($r = .53$) between an item parameter (the number of discrete prerecognition hypotheses in the Blake-Vanderplas study) and the amount of interference associated with an item, which suggests that there are characteristics of the stimulus words themselves which can determine the amount of delay in recognition. This correlation indicates that approximately a fourth of the item variance can be attributed to the subjects' confusing the stimulus words for one or more of the alternatives listed by Blake and Vanderplas (1950). Since many of these alternatives are similar in sound to the stimulus words, it can be concluded that phonetic confusions (e.g., "fear" for "theory") account for some instances of delay in recognition.

Since delay in recognition results from previous exposure to stimulus ambiguity—and presumably from interference of hypotheses formed during such an exposure—it was expected that auditory and visual recognition performance would correlate more highly when a wide range of ambiguity, rather than a narrow one, was employed. Although the correlations differed in the expected direction, both correlations were small and their difference was insignificant. The lowness of these correlations can be partially explained by the existence of factors (such as visualization and spatial orientation) which relate to recognition in one modality, but not in the other. However, it is also possible that, of the two recognition tasks, one involves the subject's ability to reject erroneous hypotheses to a greater degree than does the other. Some additional findings (in the form of regression weights relating cognitive flexibility-rigidity to perceptual recognition) would seem to indicate that this is indeed the case.

If the factor "cognitive flexibility-rigidity" is regarded as indicative of the extent to which subjects are able to reject their erroneous hypotheses, then this factor should be negatively related to scores on the recognition tests. In the present study, high cognitive flexibility was found to be associated with early recognition of auditory and, to a lesser extent, of visual stimuli, when the range of ambiguity was wide. Thus, in cases where an opportunity is given for an erroneous initial perception of the ambiguous stimulus, flexibility is implicated as a factor in auditory (and perhaps also visual) recognition. With the lessened range of ambiguity, high cognitive flexibility was once more associated with early auditory recognition. This indicates that a subject who misinterprets the stimulus under these conditions still has the problem of rejecting his initial hypothesis in favor of a more veridical interpretation. This conclusion is further supported by the similarity between the distributions of recognition points for the WRA and NRA groups over the trials which follow the starting trial used with the NRA group. (As an example of this similarity, one can compare the distributions in Figures 1 and 2 over the last eight trials.) The sole effect of eliminating the early, highly ambiguous trials seems to have been to alter the probability of immediately recognizing the stimulus.

In the case of visual recognition, the situation appears to be different. The distributions of item recognition points for the WRA and NRA groups, when compared over all trials subsequent to the initial one used with the NRA group, are highly dissimilar. (For instance, in Figures 3 and 4 the distributions for Trials 8 through 15 are skewed in different directions.) Moreover, since high cognitive flexibility was associated with *late* visual recognition when the range of ambiguity was narrow, it would appear that in the case of visual recognition, the subject in the NRA group should maintain his initial interpretation of the blurred stimulus.

In summary, several types of evidence might be said to indicate that the auditory recognition task brings into play a subject's ability to reject inappropriate hypotheses to a greater extent than does the visual task. It was found that the interference effect was more pronounced in the case of auditory recognition than it was in the case of visual recognition. In addition, the distributions of recognition points for the auditory items showed greater similarity to each other than did those for the visual items. Finally, the auditory test was more highly related to cognitive flexibility-rigidity than was the visual test. On the basis of these findings, it is concluded that the auditory recognition test is preferable to the visual test as an instrument for studying the effects of hypothesis formation on the later revision of hypotheses. Furthermore, it is suggested that the use of a visual masking technique might increase the usefulness of the visual test for this purpose.

Role of Flexibility of Closure

Recognition performance in the two modalities was related to another type of flexibility—"flexibility of closure," which can be identified with Witkin's "Field Dependence-Independence." While this ability was measured in the present study by the Hidden Figures and Hidden Patterns Tests, Witkin (1964) reports a high correspondence between these tests and his rod-and-frame test. A requirement common to all of these tasks is the separation of some item (rod or geometric figure) from the context in which it is presented. Subjects who are high in the "ability to perceive objects apart from . . . context [Witkin, 1964, p. 176]" are termed "field-independent," while those who instead produce "global" interpretations of objects together with their contexts are termed "field-dependent." Since performance on an auditory embedded-figures test is known to be highly related to performance on visual embedded-figures tests (White, 1954), it can be inferred that flexibility of closure as here measured also represents the ability to disembed auditory material.

Flexibility of closure was found to be related to late auditory recognition in both groups of subjects, presumably because a high ability to perceive embedded auditory figures enables the subject to hear words contained in the masking noise that, in turn, interfere with subsequent recognition of the masked word. Flexibility of closure was also found to be associated with poor recognition performance on the visual recognition test in the WRA group. This finding perhaps arises from the fact that a "global" interpretation of a highly blurred field is more appropriate than an analytical one, since during the early stages of blur, the only cues relevant to a correct identification are the gross characteristics of the field. (For example, the overall color "green" might lead the subject to suspect that the picture was taken out of doors.) At this point of focus, all attempts on the part of the subject to examine a field analytically are likely to lead to incorrect and needlessly specific hypotheses about the organization of the field. However, when the field is relatively articulated at the point where it first is viewed by a subject, a global interpretation is no longer needed or advantageous. Thus, flexibility of closure is somewhat negatively related to visual recognition performance in the NRA group. It is possible to speculate that, if a masking technique had been used to render the pictures ambiguous, visual recognition performance would have been positively related to flexibility of closure in both groups of subjects.

An alternative interpretation of the observed relationship between flexibility of closure and recognition utilizes the French et al. (1963) conception of flexibility of closure as an ability to retain spatial configurations in memory in spite of the occurrence of perceptual distractions. The present result suggests that a susceptibility to perceptual distractions is advantageous in the recognition situation, since such distractions can lead to the more ready modification of one's currently held hypothesis.

We have seen that, while flexibility of closure and cognitive flexibility-rigidity are highly correlated, they nevertheless serve different functions in perceptual recognition. The ability to overcome an embedding context supplied by the stimulus is clearly distinct from the capacity to overcome an assumption or "set" which the subject himself has formed with regard to the stimulus. Moreover, whenever one of these types of flexibility was associated with early recognition, the other was invariably found to accompany late recognition. It would therefore appear that the postulation of a broader dimension of cognitive functioning underlying both kinds of flexibility (Witkin, 1964, p. 180) could be misleading. Prior to making such a theoretical transition from restricted modes of cognitive functioning to more general ones, it is important to investigate the roles which each of the abilities are seen to play in other cognitive activities. When, as in the present case, separate abilities are found to serve individual functions, we can no longer account for their intercorrelation by postulating a single, more comprehensive dimension.

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