ABSTRACT

A TEST OF THE CHOICE POINTS NOTION IN HUMAN INFORMATION PROCESSING AT VARIOUS LEVELS OF UNCERTAINTY

By

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This research is an attempt to establish the relative importance of the number of stimulus dimensions in human information processing. Information Theory has led to predictions that the amount of information contained in a stimulus is directly related to the difficulty of processing. The theory advanced here is that in stimuli containing equal amounts of information but differing in the number of dimensions and number of alternatives per dimension, the number of dimensions would be directly related to the difficulty of processing. In other words, it is hypothesized that the number of dimensions is a more crucial variable than the number of alternatives per dimension.

Two experiments were conducted to test this notion. The first experiment used various geometrical forms as stimuli, whereas the second experiment employed drawings of human male faces. The task in the first experiment had to do with identifying the various dimensions of the stimuli, while in the second the subjects were required to reconstruct the faces using the various features as dimensions. In both experiments the dependent variables were the number of trials to criterion, two

measures of corrected error rate and three measures of the time it took the subjects to organize their thoughts from the time of the appearance of the stimuli until the subject's attempt at a solution. In both experiments the stimuli were presented tachistoscopically.

The results were analyzed separately for each experiment. The analyses indicate that when dealing with stimuli containing relatively small amounts of information, the more dimensions there are, the more significantly difficult the processing is. However, when dealing with stimuli containing relatively high levels of information, no significant differences were obtained between stimuli with more dimensions and fewer dimensions.

Three possible explanations were offered for the findings: (1) there was "integrality of dimensions" in stimuli containing supposedly many dimensions; (2) there was not a strong enough manipulation of the number of dimensions' independent variable; (3) the theory holds only for low levels of information but not for higher levels of information. It was suggested that further research be done controlling for (1) and (2). The results were also discussed in terms of some possible implications for the study of communication.

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CHAPTER I

INTRODUCTION

The research reported in this paper is an attempt to establish the relative importance of the number of stimulus dimensions in human information processing. The amount of uncertainty, or information, contained in a stimulus has been found to be related to human cognitive processing of the stimulus. The question to be dealt with in the studies which were conducted concerns how the number of stimulus dimensions and the number of alternatives per dimension affect the processing of the information contained in the stimulus. In other words, the question is whether the number of dimensions of the stimulus or the number of alternatives per dimension, or perhaps some interaction of both are the variables which affect the processing of information.

Information Theory as postulated by Shannon and Weaver (1949) and its application to Psychology in Attneave (1959) and in Garner (1962) deal with the amount of uncertainty in signals or stimuli. The amount of uncertainty contained in a stimulus or in an event is a function of the probability of occurrence or appearance of the stimulus or the event. The lower the probability of its occurrence, the greater the amount of uncertainty associated with it. That is to say that if a given event has a low probability of occurring, there is great doubt as to whether it will in fact occur at a given moment in time. Conversely, the higher the overall probability of occurrence of an event, the less doubt there is as to its occurrence at a given moment in time, and, thus, less uncertainty concerning its occurrence. Uncertainty is a construct that may be thought of in terms of before the fact, i.e., it deals with expectations and probabilities of occurrence of an event before it occurs.

Information, on the other hand, is a notion which may be viewed in terms of being relevant after the fact. Information, just like uncertainty, is a function of the probability of the occurrence of an event. However, information is measured in terms of uncertainty reduction. If there is little uncertainty concerning the occurrence of the event (its probability of occurrence is high) there will be little information gained if the event does in fact occur. On the other hand, if there is much uncertainty concerning the occurrence of the event (its probability of occurrence is low) then there will be much information gained (after the fact) if the event does occur.

For example, suppose a fair coin is about to be flipped. The probability of occurrence of the event "head" is one-half. If, on the other hand, a fair die is to be rolled, the probability of occurrence of the event "three" is one-sixth. The uncertainty associated with obtaining a "head" when flipping the coin is smaller than the uncertainty associated with obtaining a "three" by rolling the die. And, therefore, the amount of information gained if "head" occurs is less than the amount of information gained if a "three" occurs. More uncertainty has been reduced in the case of the die as compared to the case of the coin.

From the preceding discussion and example it should be clear that the amount of uncertainty is also a function of the number of equally likely alternative events that might occur. The more alternatives the greater

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greater the uncertainty associated with the occurrence of each outcome and the more information gained after the fact if the event does in fact occur.

What has been said till now concerns uni-dimensional cases. At this point the term "dimension" should be clarified. A dimension is "some characteristic according to which items can be placed in an order along some sort of scale" (Hilgard, 1962), or "some unit of conceptual functioning that represents the 'content' of thought" (Schroder, Driver & Streufert, 1967).

Much of the research on information processing dealt in one way or another with dimensions, though not always by that name. For example, in a classic study of concept formation (a realm of research directly concerned with information processing) Bruner, Goodnow and Austin (1956) presented subjects with stimuli in which a varying number of attributes (the term used in their research) was considered relevant. Each of the attributes had three possible alternatives or "values." The attributes (dimensions) were: number of figures, shape of figures, color of figures, number of figure borders, type of borders and color of borders. The other studies to be reviewed here also deal with stimuli containing several dimensions, most often of various geometric forms.

Even at the level of the uni-dimensional stimulus several conceptual problems exist which should be mentioned briefly. Firstly, the question of whether each of the alternatives has an equal probability of occurrence. Secondly, whether all the alternatives are known and whether the exact probability of each is known or not. The first question can be dealt with quite sufficiently by Information Theory. However, the second question is crucial since most often, in most sets of events, one does not know what all the alternatives are, and as a result one cannot know the probability of occurrence of each of the alternatives. Furthermore, in many instances each person may attach a different probability to each known alternative, thereby creating subjective versus objective probabilities.

When going beyond the uni-dimensional stimulus the issue becomes more complex. Here, the amount of uncertainty contained in the stimulus becomes a function of the number of dimensions and the number of alternatives per dimension. In order to measure the amount of uncertainty in such a situation, one needs to compute the product of $a_1 \times a_2 \times \ldots a_n$ where a_i is the number of equally likely alternatives of the ith dimension. The obtained product equals the number of possible combinations that can be constructed using the given dimensions and their alternatives. A particular case of the general rule is when each dimension has an equal number of alternatives ($a_1 = a_2 = \ldots a_n$), thus the uncertainty would be measured by a^i.

For example, if a stimulus has two dimensions, shape and color, the shape dimension having two alternatives, circle or rectangle, and the color dimension having five alternatives, a total of ten different stimuli can be constructed. Another example would be if there are four dimensions and seven alternatives per dimension, then a total of $7^4 = 2401$ different stimuli can be constructed. If we were to assume equal probabilities of occurrence for each alternative of each dimension then the probability of one particular stimulus in the first example would be one—tenth while the probability of one particular stimulus in the secon

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second example would be one to two thousand four hundred one. Of course, the uncertainty in the second example is much greater than in the first one. In any event, the central issue here is that the amount of uncertainty in the stimulus is determined by both the number of dimensions and the number of alternatives per dimension.

Shannon and Weaver (1949) suggest measuring information in units called "bits." One bit of information is gained by reducing exactly 50 percent of the uncertainty. For example, using optimal strategy without gambling on chance it would require three bits of information to guess a number chosen from among eight numbers, or five bits of information to guess a number from among 32 numbers. Numerous studies in perception have utilized the bits measure and have arrived at rather interesting conclusions concerning man's ability to remember and to process information. In one such paper by Miller (1956) which talks about the "magical number seven plus or minus two" the author maintains that man has the ability to discriminate effectively among five to nine stimuli varying on one dimension in a given period of time. In terms of bits, man's capacity is roughly between two and three bits. However, as Miller points out, when asked to deal with stimuli consisting of two dimensions, man's capacity increases, although it does not double. As more dimensions are added to the stimuli, more discrimination can take place, with each dimension adding some information. This additional processing is made possible by recoding the information.

It would seem quite obvious that the amount of uncertainty associated with a particular stimulus would affect the effort involved in the cognitive processing of that stimulus. However, an interesting question would be to what extent the number of dimensions and to what extent the number of alternatives per dimension are critical in this process, given an equal amount of uncertainty in two situations created by two different combinations of dimensions and alternatives per dimension. For example, imagine two stimuli each having the probability of occurrence equalling one-sixteenth. One such stimulus has two dimensions, each dimension having four possible alternatives; and the other stimulus has four dimensions each dimension having two alternatives. Would there be any difference in the processing of the two stimuli? Which would be processed more easily?

Information Theory employing the bit notion would predict that both stimuli would be processed in the same amount of time and with equal difficulty, since both contain four bits of information. On the other hand, Katzman (1970) would predict that the stimulus composed of four dimensions would be more difficult to process than the stimulus composed of two dimensions, even though the former has only two alternatives per dimension while the latter has twice as many, i.e., four alternatives per dimension. Katzman proposes that each dimension be viewed as a "choice point," that is, a point where the human processor must make some kind of decision concerning that dimension. Accordingly, the more choice points (or dimensions) there are in the stimulus, the more processing will take place. Furthermore, Katzman argues that the number of alternatives per choice point, or per dimension, would not be a crucial matter unless the number of alternatives becomes so great that a new choice point would become necessary.

What Katzman is advocating is a Packaging Model of information processing according to which each package (choice point) can contain a certain amount of information, and if more alternatives (or information) exist, another package will be needed. He notes: ". . . There must be at least one package for each choice point since that choice point defines the location of at least some of the information of the stimulus. The work done in processing the input stimulus is less closely related to the number of bits of information attached to the stimulus as a whole. Only insofar as information at particular choice points requires additional packages does information have an effect on processing" (Katzman, 1970, p. 13).

The packaging model seems to have face validity if one examines how people encode information. It seems plausible to generalize that people deal with choice points as individual decisions or coding units. At this point one might recall the theoretical debate which has been going on concerning parallel versus serial or sequential processing of information (Nickerson, 1967; Egeth, 1966). This paper is not directly concerned with the issue except for the fact that both parallel and sequential "strategies" might be involved with choice, be it by handling choice points together in a parallel form or in a sequential manner.

In terms of communication it seems profitable to advocate the choice point notion. In many instances people describe objects choice point by choice point. A woman would describe her dress by dealing with its style, its color, its material, its size etc. Each attribute, feature or dimension may be viewed as a choice point. A man will talk about his new automobile by referring to its various choice points: model, color, horse power etc. People describe one another in terms of their hair style, shape of their nose and so forth.

Considerable research has been done involving the relationship between the amount of information in stimuli and the processing of those stimuli. Various measures for the difficulty of the processing of the stimuli have been employed such as reaction time and error rate. Some of the data point to a positive relationship between the variables. However, as Katzman points out, several problems exist in the interpretation of those findings. The packaging model implies a step function as opposed to a linear function. Each step in the step function is analogous to a choice point in the packaging model. Up to a certain point a package can contain more and more information. When the package's limit is reached, a new package will be needed and will be reflected in a new step. The number of packages, and not the amount of information in each package nor the total amount of information in all the packages combined will affect the information processing.

Katzman claims that the obtained effect in some of the research is a result of pooling the data from all the subjects, thereby loosing sight of the step function, or of the effect of choice points since the subjects vary in their individual performance curves. By reanalyzing the data of several experiments Katzman tries to show the existence of a step function instead of the linear or almost linear functions reported by the other researchers. Also, he interprets several previous studies in terms of the choice point notion.

Alluisi, Muller and Fitts (1957) conducted an experiment in which they found that for a constant rate of presentation in bits there was

better information processing for the case in which few stimuli were presented with each drawn from a large ensemble than in the case where many stimuli drawn from smaller ensembles were presented. Katzman interprets these findings as fitting his proposed model since it is a case of what he calls repetition of stimulus form in a signal over time. Katzman maintains that fewer repetitions in the same time unit present fewer choice points according to the packaging model. Accordingly, the conclusions of the Alluisi et al., study that "For a given rate of information presentation an increased rate of information transmission was obtained by an increase in the number of possible alternative stimuli and a corresponding decrease in the rate of stimulus presentation" (Alluisi et al., page 157) confirm to Katzman's model.

In another study, Mackworth and Mackworth (1956) varied the rate of presentation of information while also varying the number of windows in which the information was presented (i.e., the choice points) in the display. Concerning this experiment Katzman points out: "They found that error rate was related to both the rate of presentation for the whole system and the number of windows. Thus if the rate per window was halved and the number of windows was doubled the error rate would go up. Again we see that not only Informational aspects of the signal but also number of choice points affect processing" (Katzman, 1970, pages 35-36).

In a study by Siegel (1969), not reported by Katzman, a more direct test of the choice points notion was made. She examined concept attainment performance as a function of form of information using three sets of stimuli that were equated for information in terms of bits, but that differed in the form in which the information was presented and shoul

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amount of information using problems with one, two, or three relevant dimensions. Siegel found that concept attainment was more difficult and a greater percentage of inconsistent hypotheses was offered by the subjects when the information was contained in three figures varying in two dimensions (color and striations) or two figures varying in three dimensions (color, striations and size) than when one figure varying in six dimensions (color, striations, size, shape, number and orientation). Concept attainment was also more difficult as the number of relevant dimensions increased. Thus, a particular amount of information in multiple figures appeared to be more difficult to remember and code than the equivalent amount of information in a single figure.

In his own series of experiments, Katzman set out to test the choice points hypothesis. His subjects were required to learn a set of numerals each of which was associated with a particular geometrical form. In one set of forms (uni-dimensional) there were six forms with each one appearing only once, some with a solid border and some with a broken border. In the other set of forms (bi-dimensional) each of two forms appeared twice, once with a solid border and once with a broken border. After the subject learned the numerals corresponding to the forms, he was given three tasks. Each subject first learned either the uni-dimensional set or the bi-dimensional set and performed the tasks before going on to the second set.

The first task was one of recognition. One of the forms was presented on a stand and the subject was required to press one button from among eight buttons in a response box which corresponded to the numeral originally associated with the form (all numerals were between

1 and 8). His reaction time from the exposure till the pressing of the button was recorded. The second task involved simple arithmetic. A card was presented which displayed three of the forms with a plus or minus signs between them. The subject had to calculate the arithmetical result and press the corresponding button in the response box (all correct results were between 1 and 8 although the interim result could have been outside that region). Here, too, the response time was recorded. For both tasks error rates were also computed. Finally, each subject was asked concerning the first two tasks which set of forms he would prefer to work with if given the choice.

The results indicated that the bi-dimensional code took more time and was less preferred than the uni-dimensional code, despite the fact that the latter contained more elements (more information). The data on error rates was in the predicted direction but not statistically significant, perhaps, according to Katzman, because of the relatively easy task in both sets.

Another experiment was conducted to add color and hatch marks instead of the two types of borders, but the results did not fully confirm the choice points hypothesis. The experiment was repeated and corrected for what seemed to be difficult color discriminability and then the hypothesis was supported on all dependent variables. It was found that the code that required two choice points required more processing than either code which only required one choice point.

The two experiments to be reported in this paper were an attempt to make a direct test of the claims made concerning the choice points notion. The first experiment dealt with stimuli consisting of simple gene

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geometrical forms. The second experiment used pictures of human faces as stimuli. The main advantage in these experiments as compared to the work of Siegel and Katzman is that its designs reached relatively high levels of information in the stimuli by utilizing several choice points and several alternatives per choice point. Another advantage is that the first experiment required the subjects to respond in a sequential manner, choice point after choice point, while the second experiment allowed the subjects to respond to all choice points simultaneously if they so wished. A third advantage is the measurement of the time it took the subjects to "organize their thoughts" or to process the information. This measure was used instead of the more often used method of reaction time. A more detailed discussion of these points will follow the presentation of the results.

The main hypothesis (H_1) to be tested was: Given two stimuli each containing an equal amount of information, the stimulus with more choice points (therefore fewer alternatives per choice point) will be more difficult to process than the stimulus with the fewer choice points (and, therefore, more alternatives per choice point).

Two additional hypotheses were tested aimed at giving further support to the theoretical notions advanced in this paper. Both hypotheses complement one another in that they test the relative contribution of the number of choice points and the number of alternatives per choice point in processing the information contained in the stimuli.

The first of the two, H_2, was: Given a constant number of alternatives per choice point in a set of stimuli, the number of choice points is directly related to the difficulty of processing the stimuli.

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The second of the two, H_3, was: Given a constant number of choice points in a set of stimuli, the number of alternatives per choice point is directly related to the difficulty of processing the stimuli.

H_2 and H_3 are both expressions of the basic notion that difficulty of processing is directly related to the total amount of information presented by the stimulus. Previous research has indicated that if the number of alternatives per choice point is increased, processing becomes more difficult. The experimental design allowed a test of this notion in H_3. However, the packaging model maintains that if the number of alternatives per choice point increases within a limited range, there should be no increase in the difficulty of processing. H_2 also tests the effects of increased uncertainty but emphasizes the effect of the choice points. Furthermore, H_2 is a broader test of the model than H_1 since the amount of information increases with the increase in choice points. Accordingly, if H_1 and H_2 yield significant results while H_3 does not, the implications will be that choice points are more relevant to information processing than alternatives per choice point.

CHAPTER II

METHOD

Experiment 1

Subjects

The subjects in Experiment 1 were 18 males and 18 females, all sophomores and juniors enrolled in a communication course at Michigan State University. All Ss took part in the experiment as a partial requirement for the course work.

Apparatus

The stimuli. The stimuli in Experiment 1 consisted of 38 color transparancies. All were constructed so as to contain each of five distinct attributes (choice points). Each choice point had four possible alternatives. The choice points and the alternatives were as follows:

1. An external geometric form (retangle, oval, square, circle).
2. The color of a solid equalateral triangle located within the external form (red, blue, green, yellow).
3. The direction which the triangle pointed (left, right, up, down).
4. Type of figures forming the border of the triangle (Xs, asterisks, plusses, small circles).
5. The direction of hatch markings within the form and behind the triangle (diagonal left to right, diagonal right to left, horizontal, vertical).

The original design included using the border of the external geometric form as the sixth choice point. Therefore, there were four kinds of borders, all in orange, and differing in the length of the border sections. However, based on the pretest results, which showed poor discriminability of the four borders, it was decided to use only the five choice points mentioned above.

Figure 1. An example of the transparancies used in Experiment 1.

The stimuli were photographed on a black background using Kodachrome film. The measurements of the various components of the stimuli from which they were photographed were as follows:

1. Outer figure:

   rectangle- 7 3/4" X 5"

   oval- 7 11/16" X 5 1/2" (at its most extreme points)

   square- 7" X 7"

   circle- 7 1/2" (diameter)

2. Central triangles: 2 15/16" (each side) made from "Coloraid" paper of maximally discriminable hues

3. Triangle borders: all contained within 1/2" X 1/2" squares

4. Hatch marks: lines 1/32" wide, 1/4" apart from one another

Table 1 presents the composition of the 38 stimuli used in the experiment. The numbers assigned to the stimuli in this table will be used throughout the thesis.

Table 1. The composition of the stimuli used in Experiment 1.

Stimulus number	Triangle color	Hatch marks	External form	Triangle border	Triangle direction
1	blue	\\\	rectangle	xxxxxxxx	left
2	red	\\\	rectangle	********	left
3	blue	///	oval	xxxxxxxx	right
4	red	///	oval	********	right
5	blue	\\\	rectangle	********	right
6	blue	///	oval	********	left
7	red	\\\	rectangle	xxxxxxxx	right
8	red	///	oval	xxxxxxxx	left
9	blue	\\\	oval	********	left
10	red	\\\	oval	********	left
11	blue	\\\	oval	xxxxxxxx	right
12	red	///	rectangle	xxxxxxxx	right
13	blue	///	rectangle	********	left
14	red	///	rectangle	xxxxxxxx	right
15	blue	///	rectangle	********	right

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Table 1 (cont'd.)

Stimulus number	Triangle color	Hatch marks	External form	Triangle border	Triangle direction
16	red	///	oval	********	right
17	blue	///	oval	xxxxxxxx	left
18	red	\\\	rectangle	xxxxxxxx	left
19	blue	\\\	rectangle	********	right
20	red	\\\	oval	xxxxxxxx	left
21	green	\\\	rectangle	oooooooo	up
22	green	|||	oval	oooooooo	up
23	green	|||	circle	********	left
24	red	|||	circle	oooooooo	right
25	green	///	circle	oooooooo	up
26	green	|||	circle	xxxxxxxx	left
27	blue	|||	circle	oooooooo	up
28	blue	///	rectangle	xxxxxxxx	up
29	green	\\\	oval	oooooooo	up
30	green	|||	circle	********	right
31	green	|||	circle	oooooooo	up
32	red	|||	circle	oooooooo	left
33	yellow	≡	square	++++++++	down
34	yellow	///	oval	++++++++	left
35	yellow	≡	square	oooooooo	down
36	yellow	\\\	square	++++++++	right
37	yellow	≡	square	xxxxxxxx	down
38	yellow	≡	circle	++++++++	down

In addition to the stimulus transparencies, another set of color transparencies was prepared to be used as the "choice slides" (see procedure). Each such transparency contained two, three or four of the alternatives of one of the choice points. These, too, were photographed with Kodachrome film using a black background.

Each alternative for each choice point was either painted or glued to a 8" X 8" piece of white paper. In the case of the triangle colors, the whole triangle was Coloraid paper of the appropriate hue. In the case of the hatch marks, the entire surface of the white squares was covered with hatch marks in the desired direction. In the case of the external forms, the proper form was drawn in the exact size used for the stimuli. In the case of the triangle borders, each white square had a horizontal line six inches long composed of one type of border. And in the case of the triangle directions, each white square contained an outline of a triangle of the exact stimulus size pointing in a given direction.

The white squares were photographed on a black background. When two alternatives of any attribute were photographed, they were set up side by side with ten inches of background separating them. When three alternatives were photographed they were set up as a pyramid, and when four alternatives were photographed they were set up in a diamond arrangement.

The equipment. The experiment was conducted in an air-conditioned room, 14' X 19', equipped with blinds which created total darkness. The S was seated behind a table facing the short wall, on which there hung a white screen. S sat six feet from the screen. On the center of S's table was a 8" X 10" metal response box containing: (1) a toggle "ready" switch; (2) a set of small flat push buttons corresponding to the alternatives of the particular experimental condition. The push buttons were affixed to the response box in the position corresponding to the squares containing the alternatives on the "choice slides," i.e., horizontal, pyramid of diamond pattern; and (3) a green bulb labeled "right" and an amber bulb labeled "wrong." Three such response boxes were constructed, one for each of the alternative's conditions.

The control table which was situated behind S's table, included the following equipment: (1) two remote control Kodak Carousel slide projectors; (2) a Standard timer calibrated to .01 second units; (3) a photo-cell relay system, and (4) a monitoring box containing four nixie tubes to indicate which response button had been pushed, switches which activate the "right" and "wrong" lights on S's response box, and a control switch for the timer.

The first slide projector was used to flash the "target slides" (stimuli) which were arranged in one slide tray. The slide advance mechanism was fastened in front of E on his table. Attached to the lens of the projector was a tachistascopic shutter (Lafayette Model) and a cable shutter release which E could operate.

The second slide projector was used for the "choice slides" (alternative slides). Nine "choice slide" trays were prepared, one for each of the cells in the experimental design. Each such tray contained four sets of slides, each set made up of one slide for each choice point that was relevant in the particular cell (see Table 2). Accordingly, the trays for the 2-choice points conditions had four sets of two slides each, the 4-choice points conditions had four sets of four slides each and the 5-choice points conditions had four sets of five slides each.

In each of the four sets of "choice slides" the positions of the various alternatives were varied. In the trays for the 4-alternatives cells alternatives in each "choice slide" were rotated to four different positions. In the trays for the 3-alternatives cells, since there were only three alternatives, one had to appear in the same position twice. And in the trays for the 2-alternatives cells, each of the two alternatives appeared twice in the same position.

In the first slot in each tray, and in the slot following each set of "choice slides," an opaque slide was inserted. It served as a divider between each set of "choice slides," and was necessary since the projector advanced automatically when S responded, and feedback had to be given to him at the end of each set of "choice slides," before going on to a new set of "choice slides."

The slide advance mechanism of the "choice slides" projector was linked to S's response box so that when the "ready" switch was pulled by S, the slide projector advanced by one slide. The circuitry was such that the "choice slides" projector also advanced when a response was made by S, either correct or incorrect, i.e., when any of the push buttons was depressed.

The photo-cell relay system was designed so that when the "target slide" was flashed on the screen, the timer started automatically. The timer was stopped when S pulled the "ready" switch. Thus the system automatically measured the duration between the presentation of the "target slide" and the "ready" indication.

In addition to this equipment, E had on his table a booklet containing the pre-coded answer sheets for S's responses, and a small highintensity lamp right above the booklet, so that E could record S's responses as they appeared on the nixie tubes and the timer.

Procedure

Thirty-six subjects took part in the experiment, which was divided into three major conditions according to the number of alternatives; a 2-alternatives' condition, a 3-alternatives' condition and a 4-alternatives' condition. Twelve Ss, six males and six females were run in each of these conditions. There was also a subdivision of each of the three main conditions based on the number of choice points (2, 4 and 5). Thus, there resulted a 3 X 3 matrix, with 12 subjects running in all the 2-alternatives' cells, another 12 Ss in the three 3-alternatives' cells and the last 12 Ss in the three 4-alternatives' cells.

Ss were randomly assigned to the six possible running orders* in each of the alternative's conditions (the male and female Ss were separately assigned so that one of each would run in each running order).

Since the design of the experiment called for nine sub-conditions, it was necessary to determine which choice points and which alternatives would be considered relevant in each cell. Table 2 shows the choice points and the alternatives used in each cell. It was decided to use the triangle color choice point with red and blue alternatives and the hatch marks choice point with the two diagonal alternatives in the 2-alternatives and 2-choice points' condition, and then to add additional choice

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*2-4-5 choice points; 2-5-4 choice points; 4-2-5 choice points; 4-5-2 choice points; 5-2-4 choice points; and 5-4-2 choice points.

Table 2. The relevant choice points and alternatives per choice point in the nine experimental conditions.

Number of alternatives	Number of choice points: 2	4	5
2	triangle color (red, blue) hatch marks (two diagonals)	triangle color (red, blue) hatch marks (two diagonals) external form (retangle, oval) triangle border (exes, asterisks)	triangle color (red, blue) hatch marks (two diagonals) external form (rectangle, oval) triangle border (exes, asterisks) triangle direction (left, right)
3	triangle color (red, blue, green) hatch marks (two diagonals, vertical)	triangle color (red, blue, green) hatch marks (two diagonals, vertical) external form (rectangle, oval, square) triangle border (exes, asterisks, circles)	triangle color (red, blue, green) hatch marks (two diagonals, vertical) external form (rectangle, oval, square) triangle border (exes, asterisks, circles) triangle direction (left, right, up)
4	triangle color (all four) hatch marks (all four)	triangle color (all four) hatch marks (all four) external form (all four) triangle border (all four)	triangle color (all four) hatch marks (all four) external form (all four) triangle border (all four) triangle direction (all four)

points and alternatives for the other conditions. This particular order was chosen so as to introduce the three attributes of the triangle separately and to separate the direction of the hatch marks from the direction of the triangle since the lines might appear as intermingling.

Two of the stimuli (numbers 1 and 2) were used in each of the nine experimental conditions. This allowed analyses of responses to identical stimuli under different experimental conditions. Also, stimuli number 3 and number 4 appeared in all the 2-choice point conditions, stimuli number 9 and number 10 in all the 4-choice point conditions and stimuli number 15 and number 16 in all the 5-choice point conditions. The complete assignment of stimuli can be seen in Table 3 (in their order of presentation).

Each S was run individually. S was led into the experimental room and seated before the appropriate response box, facing the screen. E then told S: "The experiment we are about to start deals with how people perceive different things. On the screen in front of you we will be showing you two different kinds of slides. The first kind is called a 'target slide' and an example of it looks like this." Here E showed S a sample "target slide." The target remained on the screen as E continued: "As you can see, this 'target slide' is made up of several things. Now, during the experiment we will be showing you several of these 'target slides'; however, we will be showing them to you in a flash, like this . . ." At this point E set the shutter and flashed the "target slide" twice for a duration of 100 msc on each flash. The light source was a 500 watt bulb. Then E continued: "What we would like you to do is to organize your thoughts concerning the 'target slide' as it appears on the screen. Do so as quickly as you possibly can and as accurately as possible. When you think that you are ready, that is, when your thoughts are organized, pull this 'ready' switch." S was shown the switch marked "ready." "What will happen is that by pulling the 'ready' switch, you

Table 3. The 38 stimuli used in their order of appearance in each of the experimental conditions.

	2-choice points	4-choice points	5-choice points
Two alternatives	8 6 5 1 3 2 7 4	13 14 2 12 11 10 1 9	20 1 17 16 19 18 2 15
Three alternatives	3 21 22 1 23 2 4 24	2 28 25 9 1 26 27 10	29 15 32 2 30 1 16 31
Four alternatives	3 34 33 2 1 4 22 21	2 36 25 1 35 9 10 26	38 16 1 30 15 37 2 29

will expose a new kind of slide on the screen. This new kind of slide we will call the 'choice slide.' Why don't you try and pull the switch?"

S would then pull the switch and the first "choice slide" would appear on the screen. E then continued: "What we want you to do now is to decide which of these things is the one you saw in the original 'target slide' that was flashed on the screen before. Do you know which one it was?" S would indicate one of the alternatives E then responded: "Alright, now let's check and see" and put the original "target slide" back on the screen. "O.K., now what you should do is push the button which is in the same position on your box as the correct choice, concerning what you see in the 'target slide.'" S would push the button and a new "choice slide" automatically appeared on the screen for the next choice point. E then went on: "As you can see, when you press the button you will automatically advance the slide projector and expose a new 'choice slide,' and again you must make a decision concerning another one of the things you saw in the original 'target slide.' You will do this for each 'choice slide' until no more appear on the screen." The procedure continued with all the "choice slides" and then an opaque slide would make the screen appear blank.

E then continued: "Now, if you did all the choices correctly, you will get this information for me . . ." and he demonstrates the "right" flash of green light on S's response box. "However, if you were wrong, that is, if you made any error, at least one error in at least one of the choices that you made, then you will get this information from me . . ." and E demonstrates the "wrong" flash of amber light on the response box. "If you are right, that is, if you get the green light, we will go on to a new 'target slide' and proceed exactly in the same way. But, if you made an error, and the amber light went on, then you will be given another flash of the same 'target slide' that you saw before, and then you will have to make a new set of choices. You will do this until you get them all correct. Now, there are three things that I would like to point out at this time. First, when you see the 'choice slide' with the colors on it, we would like you to respond to the color of the triangle and not to the border (S is told this to avoid possible confusion since the border color is orange and one of the triangle colors is red). Second, you will notice that if you have to go through the choices more than once for any 'target slide,' the positions of each of the choices will change on the screen. This is O.K. You just respond to what you see. And third, we will be giving you true information on how you did, the green light for being right and the amber light for being wrong." E asked if there were any questions, and if there were, they were answered. Most of the Ss had no problems understanding the experimental procedure. The few that asked questions needed only brief repititions of some part of the procedure. Then E said: "We are now ready to begin. Each time before the 'target slide' is flashed I will ask you if you are ready. Only after you say 'yes' will I flash the 'target slide' on the screen. Are you ready?"

As the actual experiment begins, the tray containing the "choice slides" of the particular cell is on the "choice slides" projector, with the first opaque slide "showing." E flashed the first "target slide" for 100 msc. The size of the "target slide" on the screen was approximately 24" X 16".

As the "target slide" flashed, the timer began. When S finished organizing his thoughts, he pulled the "ready" switch stopping the timer, and at the same time automatically presented the first "choice slide." S then responded by pressing one of the push buttons on his response box. The corresponding nixie tube would glow and E would record S's response. By responding, S had automatically advanced the next "choice slide," and he would then respond to it. E recorded this response. When all the choice points were presented an opaque slide would appear. At this point E recorded the time that S took to organize his thoughts and reset the timer to zero. E then compared S's responses to the correct responses on the answer sheet.

If no error occurred, E flashed the green "right" light for about two seconds and said: "We will now go on to a new 'target slide,' are you ready?" When S responded in the affirmative, the next "target slide" was flashed. The procedure was then repeated.

If on the other hand, at least one error was made, E flashed the amber "wrong" light for about two seconds, and said: "We will now do the same 'target slide' over again. Are you ready?" The same "target slide" was flashed and the same procedure was followed. This could have happened 12 times with each "target slide." If S did not manage to get all the responses correctly on any one trial by the end of 12 trials, E said: "O.K., now let's go on to a new 'target slide'" and a new "target slide" was shown. It should be noted that E did not tell S on how many choice points errors were made.

At the end of the first cell and its eight "target slides" E said: "Let's take a short break now." During the break E changed the tray of the "choice slides" to the appropriate tray for the next cell. When E was ready he said: "Now we would like you to respond to the following things" and showed S, slide by slide, the "choice slides" that S would be responding to in the next cell. E repeated this twice and then said: "Are you ready?" and then the experiment proceeded. At the end of the second cell another break was taken and the third tray was installed on the projector. Then the experiment continued in the same manner. Following the third cell, E explained the purpose of the experiment to S.

It is important to note that the four different sets of "choice slides" which were described earlier were used so as to prevent S from learning and memorizing where the correct alternative of a particular choice point appeared on the screen. To prevent the learning of the order of the four sets, they were presented in a pre-determined random order. Thus, E had to reset the "choice slides" tray to the correct position on the projector before each trial on every "target slide."

All Ss were run by the same E (the author) during a period of eight days. One to six Ss ran each day. The average experimental session lasted 45 minutes with little variability among the Ss. The experimental sessions were held at various times during the day, from 8 a.m. to 8 p.m. The experimental conditions were distributed randomly over days and times of day.

Experiment 2

Subjects

The subjects in Experiment 2 were 15 males and 15 females, all sophomores and juniors enrolled in a communication course at Michigan

State University. All Ss took part in the experiment as a partial requirement of the course work.

Apparatus

The stimuli. The stimuli in Experiment 2 were six slides containing black line drawings of human male faces each containing the following eight features (choice points): chin and ear combinations, hair, eyes, nose, eyebrows, glasses, mouth and mustache. There was also one slide used for practice.

In order to construct the six faces, four alternatives of each of the features were chosen from an Identi-Kit, a device used extensively in criminology for identification by construction of facial likenesses.* The four alternatives of each of the features were judged to be highly discriminable by several judges. Since there were six faces and four alternatives per feature, each alternative was used once and two of the alternatives were used a second time. The slides were black lines on a white background and were photographed in those colors using Kodak film. Each face took up almost the whole area of the slide. See Figure 2 for an example of one of the faces.

The alternatives used were the actual Identi-Kit celluloid pieces. Each alternative of each feature was printed on a 5" X 4" piece of transparent celluloid. Across the top and the bottom of each piece a one-half inch wide strip of white paper was glued to mask off the serial number printed on the celluloid pieces. On the back of the white strips

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*I wish to thank the Identi-Kit Company of Newport Beach, California, for lending us the Kit.

Figure 2. An example of the faces used in Experiment 2.

there was a special code used by E to record S's responses.

In addition to the slides and the alternative celluloids, special "frames" were prepared. The "frames" were celluloid pieces of the same size as the alternative pieces and contained printed combinations of the features that the Ss were not asked to deal with for a particular face. Since the Ss were asked to deal with 2, 3, 4, 6 and 8 features, four "frames" were prepared for each face. When all eight features were relevant no "frame" was used. One frame contained six features (chin-ears, glasses, eyes, mustache, eyebrows and nose) for the two relevant features condition; one contained five features (chin-ears, glasses, eyes, mustache, and eyebrows) for the three relevant features condition; one contained four features (chin-ears, glasses, eyes and mustache) for the four relevant features condition; and one contained two features (chin-ears and glasses) for the six relevant features condition. This particular order was chosen so as to make the subject look at the whole target area with the relevant features balanced spatially around the faces. See Appendix for examples of the features and the "frames."

The equipment. The experiment was conducted in the same room as Experiment 1. S was seated behind a table, nine feet from a wall on which a white square screen hung. The table had a white paper covering so that the celluloid pieces laid upon it could easily be seen. On S's table there was an electric cable with a push button on its end. By pressing the button, S would stop a timer (Standard Model) calibrated at .01 second units, which would begin running by means of a photo-cell relay system when the face slide was shown on the screen. This allowed for the measurement of time that elapsed between the slide presentation and the beginning of the reconstruction of the face by S.

In front of S's table was a small stand on which a Kodak Carousel slide projector was set up facing the screen. It was equipped with a tachistascopic shutter (Lafayette Model) and a cable shutter release which E could operate. The projector was used to project the faces on the screen. Their size was approximately 14" X 10". The amount of light in the experimental room was controlled by the photo-cell meter. Enough light was allowed for S to work on reconstructing the faces.

On E's table, which stood behind S's table lay the piles of alternatives for each of the features and the pre-coded answer sheets. At E's right was the timer.

Procedure

Thirty Ss took part in the experiment. Each S was presented with all six face slides. There were six experimental conditions, and one of the face slides was used for each S in each of the conditions. Table 4 shows the experimental conditions.

Table 4. The six experimental conditions of Experiment 2.

	Two alternatives	Four alternatives
16 possible combinations	$2^4 = 16$	$4^2 = 16$
64 possible combinations	$2^6 = 64$	$4^3 = 64$
256 possible combinations	$2^8 = 256$	$4^4 = 256$

Each of the thirty Ss was run in a different randomized order of the six experimental conditions. In each experimental condition five Ss responded to one of the faces, five other Ss responded to a second face and so on. Thus, each face was used five times in each experimental condition.

Each S was run individually. He was led into the experimental room and seated behind his table. E began by saying: "This is an experiment that has to do with how people perceive different things. In particular we are interested in how people perceive human faces. On the screen in front of you we will show you several slides of human male faces, one slide at a time. What we would like you to do is to organize your thoughts concerning the face that you will be shown and then try to reconstruct it. You will reconstruct the face with the aid of these different pieces containing the different features." E then began putting eight piles of two alternatives each, for all the eight features of the practice face, on S's table, with the response code facing down. E continued: "What you should do is pick the piece containing the correct feature that was part of the face that you will be shown. Do this for each of the features. Put one on top of the other and try to come up with the exact face that you saw on the screen. Now, we will be showing you the face for a short period of time, like this" and E flashed the practice face on the screen for 1.0 seconds. S was then asked to try and reconstruct the face. When S indicated that he was finished, E continued: "I will be sitting behind you. When you think you are done, that is, when you have reconstructed the face exactly as you saw it, please hand me the entire pack of features. I will check it and let you know how you have done. All I will tell you is if you did it correctly or not. I will not tell you how many errors you made, nor in which features they were made. If you get all the features correctly, we will go on to a new face. However, if you do not get it correctly, that is, if you make at least one error, I will show you the face again, for the same period of time, and you will try to reconstruct it again. We will do this over and over until you reconstruct it correctly." E then checked the practice face and told S whether it was correct or not. If it was correctly done, the experiment was ready to begin. If not, the face was shown again and the same procedure was followed for a second attempt. If this attempt also failed, S was shown the slide for a prolonged period of time and was asked to compare it with his reconstruction of it and to locate his errors. When this was done, or following the correct first attempt, E said: "O.K., this has been a practice face. In the real experiment you will have to do it over and over until you get it correctly and each time you will only see the slide for a short period. For the next few faces we will sometimes be asking you to deal with all eight features just like you have done now. But, sometimes we will ask you to deal only with 2, 3, 4 or 6 features. If you have to deal with less than eight features, we will give you a 'frame' which has the correct features that you don't need to deal with." E then gave S an example of a "frame" and continued: "Also, sometimes we will ask you to select the correct feature from among two alternatives just like you have done now, and sometimes from among four alternatives. Are there any questions?" At this point questions were answered. E continued: "And finally, try to organize your thoughts concerning the face that you will be shown as quickly as you can. When you are ready to begin reconstructing the face, press this button." E showed S the cable with the button. "So that you are sure to press the button, please hold the cable in your hand while the slide is shown and do not touch the pieces on the table before you press the button. After you have pressed the button, put the cable down and you may proceed to reconstruct the face."

E then put the appropriate piles of alternatives and the "frame," if called for, on S's table and prepared the correct slide in the projector. Then the experiment began. E released the shutter after S indicated that he was ready. Then E sat down behind S and waited for him to hand over the pack. When the timer stopped (by S pushing the button) E recorded the time and reset the timer. After S handed the pack to E, it was checked and the answers recorded and compared to the answer sheet. Then, based on S's performance, E either said "Perfect, let's go on to a new face" or "No, we'll have to do this face again." If S did not manage to get the face correctly after 12 attempts, E said: "No, but let's go on to a new face anyway." This procedure was repeated for the six slides. For the faces in which two alternatives per feature were presented, the incorrect alternatives were determined in advance on a random basis.

All Ss were run by the same E (the author) during a period of 10 days, one to five Ss per day. The average experimental session lasted 50 minutes with some variability (between 35 to 75 minutes). The experimental sessions were held at various times during the day from 9 a.m. to 6 p.m. The experimental conditions were distributed randomly over days and times of day.

CHAPTER III

RESULTS

Dependent Variables

The same six dependent variables were used in both experiments. The first dependent variable was the number of trials S needed to accomplish the task without error, i.e., trials to criterion (TTC). The Ss were allowed a maximum of 12 trials for each stimulus in both experiments. In the event that they did not complete the task by the twelfth trial, it was recorded as if 13 trials were required. The lowest possible score on TTC was unity.

The second dependent variable was the corrected error rate made by S on the first trial of each stimulus (CER1). Since the number of alternatives and choice points are factors which could influence the probability of getting the task accomplished without errors by mere guessing, a correction factor was introduced to take account of these chance occurrances.

The formula used for the correction was:

$$\text{corrected score} = 1 - \frac{\text{alts}\left(1 - \dfrac{\text{total errors}}{\text{cps X trials}}\right) - 1}{(\text{alts} - 1)}$$

where alts equal number of alternatives and cps equal number of choice points. This formula takes into account the total number of errors made by S relative to the possible number of errors he could have made, corrected for the number of alternatives per choice point. The lowest possible score would be 0.000 indicating no errors. A score of 1.000 indicated errors occurring at the rate expected by mere guessing and a score greater than 1.000 indicated errors occurring more frequently than would be expected by mere guessing.

The third dependent variable was the mean corrected error rate per trial based on all the trials of a particular stimulus (MCER). Here, too, a correction was necessary and the same correction formula was used as in CER1.

The fourth dependent variable was the time it took the subject to organize his thoughts and process the information on the first trial for a given stimulus (PT1). This time was measured from the time the stimulus ("target slide" or face) was exposed on the screen until the time S pulled the "ready" switch or pushed the button. This time was recorded in fractions of a second to the nearest hundredth.

The fifth dependent variable was the time it took S to organize his thoughts and process the information on the correct trial for a given stimulus (PTC). The time was measured and recorded in the same manner as for PT1. If only one trial was necessary PTC would be equal to PT1. If S did not accomplish the task without error in 12 trials, PTC was not used in the computations for that particular S on the given stimulus. The number of Ss was accordingly reduced in further computations. It should be noted that this occurred only twice.

The sixth and final dependent variable was the mean time it took S to organize his thoughts and process the information on all his trials for a given stimulus (MPT). It was measured and recorded as the previous two dependent variables. If only one trial was required all three processing time measures would be equal.

In Experiment 1 the first two "target slides" in each of the experimental cells were used for practice and were accordingly excluded from the computations. Thus, the data in Experiment 1 is based on six "target slides" per subject in each of the experimental cells. Furthermore, in order to get more stable measures on the dependent variables, and given no reason to suspect that the different "target slides" in each experimental cell were different from one another on any relevant variable, means for the six measures for each subject across all the "target slides" in each cell were computed. In other words, each of the measures is based on six "target slides."

In Experiment 2, following the practice face, each subject was exposed to all six faces and thus, each subject served as his own control in all the experimental conditions. The original design of the experiment called for the use of two faces in each experimental condition in order to get more stable measures. However, a pretest with several Ss indicated that this would require an experimental session of approximately two hours, which was thought to be too long for the Ss.

Experiment 1

Several statistical analyses were performed with the data from Experiment 1.

Tables 5-9 summarize the results of analyses of variance for repeated measures done on the complete matrices for all the dependent variables except for TTC because the number of trials to criterion cannot be corrected for guessing over different uncertainty levels, whereas not having it corrected would lead to spurious results. The analyses are based on the design offered by Winer (1962, pages 302-309). The number of alternatives was taken to be the treatment variable and the number of choice points was taken to be the measurement variable. According to H_2 and H_3 significant main effects of choice points and of alternatives were expected whereas no significant interactions were predicted.

Table 5. Means and analysis of variance for repeated measures for CER1--corrected error-rate on first trial in Experiment 1.

Source	Sum of squares	Degrees of freedom	Mean square	F
Between subjects	0.5160	35	0.0147	
Alternatives	0.0298	2	0.0149	1.0105
Subjects within alternatives	0.4862	33	0.0147	
Within subjects	2.4575	72	0.0341	
Choice points	1.5588	2	0.7794	60.9263*
Alternatives X choice points	0.0545	4	0.0136	1.0650
Choice points X subjects-in-alternatives	0.8443	66	0.0128	
Total	2.9735	107		

*p<.01

Means

Alternatives \ Choice points	2	4	5	Mean
2	0.04	0.35	0.36	0.25
3	0.07	0.26	0.31	0.21
4	0.06	0.30	0.30	0.22
Mean	0.06	0.30	0.32	0.23

Table 6. Means and analysis of variance for repeated measures for MCER--mean corrected error-rate per trial in Experiment 1.

Source	Sum of squares	Degrees of freedom	Mean square	F
Between subjects	0.3894	35	0.0111	
Alternatives	0.0684	2	0.0342	3.5134*
Subjects within alternatives	0.3210	33	0.0097	
Within subjects	1.5165	72	0.0211	
Choice points	0.9397	2	0.4698	57.4110**
Alternatives X choice points	0.0367	4	0.0092	1.1217
Choice points X subjects-in-alternatives	0.5401	66	0.0082	
Total	1.9059	107		

*p<.05
**p<.01

Means

Alternatives \ Choice points	2	4	5	Mean
2	0.06	0.30	0.31	0.22
3	0.06	0.20	0.23	0.16
4	0.06	0.24	0.24	0.18
Mean	0.06	0.25	0.26	0.19

Table 7. Means and analysis of variance for repeated measures for PT1--processing time on first trial in Experiment 1.

Between subjects	269.4575	35	7.6988	
Alternatives	13.8547	2	6.9273	0.8944
Subjects within alternatives	255.6029	33	7.7455	
Within subjects	264.3534	72	3.6716	
Choice points	106.8256	2	53.4128	23.3382*
Alternatives X choice points	6.4775	4	1.6194	0.7076
Choice points X subjects-in-alternatives	151.0503	66	2.2886	
Total	533.8109	107		

*p<.01

Table 7 (cont'd.)

Means

Alternatives \ Choice points	2	4	5	Mean
2	1.91	3.92	3.55	3.13
3	2.19	5.07	4.68	3.98
4	2.19	3.79	4.19	3.39
Mean	2.09	4.26	4.14	3.50

Table 8. Means and analysis of variance for repeated measures for PTC--processing time on correct trial in Experiment 1.

Source	Sum of squares	Degrees of freedom	Mean square	F
Between subjects	248.5484	35	7.1014	
Alternatives	12.6821	2	6.3411	0.8872
Subjects within alternatives	235.8663	33	7.1475	
Within subjects	271.6826	72	3.7734	
Choice points	111.1509	2	55.5755	23.6800*
Alternatives X choice points	5.6340	4	1.4085	0.6001
Choice points X subjects-in-alternatives	154.8977	66	2.3469	
Total	520.2310	107		

*p<.01

Means

Alternatives \ Choice points	2	4	5	Mean
2	1.86	3.86	3.77	3.16
3	2.19	4.92	4.82	3.98
4	2.19	3.68	4.33	3.40
Mean	2.08	4.15	4.31	3.51

Table 9. Means and analysis of variance for repeated measures for MPT--mean processing time on all trials in Experiment 1.

Source	Sum of squares	Degrees of freedom	Mean square	F
Between subjects	6.6868	35	0.1911	
Alternatives	0.3476	2	0.1738	0.9048
Subjects within alternatives	6.3392	33	0.1921	
Within subjects	7.6762	72	0.1066	
Choice points	3.2498	2	1.6249	25.0810*
Alternatives X choice points	0.1506	4	0.0377	0.5812
Choice points X subjects-in-alternatives	4.2758	66	0.0648	
Total	14.3630	107		

*p<.01

Means

Alternatives \ Choice points	2	4	5	Mean
2	1.94	3.82	3.83	3.20
3	2.21	5.09	4.80	4.03
4	2.26	4.00	4.51	3.59
Mean	2.14	4.30	4.38	3.61

As can be seen from the tables, a highly significant choice points' main effect was obtained on all the dependent variables. As for the alternatives' main effect, only in the case of MCER was significance reached. No significant choice points by alternatives' interaction was obtained either. In general, then, H_2 was confirmed pointing to the fact that given sets of stimuli containing a constant number of alternatives, the more choice points contained in the stimuli, the more difficult the processing. Except for MCER, H_3 was not confirmed thus no support was obtained for the hypothesis that given sets of stimuli containing a constant number of choice points, the more alternatives contained in the stimuli, the more difficult the processing.

H_1 was put to a test by comparing the two cells in the matrices in which there was an equal amount of information--16 possible combinations (two alternatives and four choice points versus four alternatives and two choice points) and also by comparing the two cells in the matrices in which the amount of information was almost equal--243 combinations (three alternatives and five choice points) versus 256 combinations (four alternatives and four choice points). The comparisons were made using one-tailed t-tests between the means of the respective cells. This was done for all dependent variables. The number of degrees of freedom was 22. Tables 10 and 11 present the results of these tests.

Table 10. Comparison of the means in the two alternatives and 4-choice points' condition to the means in the four alternatives and 2-choice points' condition for all the dependent variables.

Dependent variable	Two alternatives 4-choice points	Four alternatives 2-choice points	t	p
TTC	2.03	1.13	4.90	<.001
CERI	0.35	0.06	5.94	<.001
MCER	0.30	0.06	6.47	<.001
PT1	3.92	2.19	2.39	<.05
PTC	3.86	2.19	2.39	<.05
MPT	3.82	2.26	2.28	<.05

Table 11. Comparison of the means in the three alternatives and 5-choice points' condition to the means in the four alternatives and 4-choice points' condition for all the dependent variables.

Dependent variable	Three alternatives 5-choice points	Four alternatives 2-choice points	t	p
TTC	2.61	2.69	-0.18	n.s.
CER1	0.31	0.30	0.27	n.s.
MCER	0.23	0.24	-0.35	n.s.
PT1	4.68	3.79	0.92	n.s.
PTC	4.82	3.68	1.42	n.s.
MPT	4.80	4.00	0.92	n.s.

As can be seen, all the t-tests in Table 10 were significant in the expected direction while in Table 11 no t-test reached significance.

The final analyses of the data from Experiment 1 dealt with those "target slides" which were presented in more than one condition to all the subjects. First, when a "target slide" was presented in all the alternatives' conditions holding constant the number of choice points, H_3 would predict that the more alternatives per choice point, the more difficult the processing. In the cases of "target slides" in the three cells being compared ("target slides" numbers 4, 9 and 10) a simple analysis of variance was computed for each of the dependent variables. The degrees of freedom were 2 and 33. In the cases where the "target slides" were only compared in two cells (due to an unfortunate error in the design stage of the experiment) t-tests were computed for which the number of degrees of freedom equalled 22. This was done for "target slides" numbers 15 and 16. The scores in all cases were based on single measurements per subject for each "target slide."

Of the 18 analyses of variance done, only one, for "target slide" number 10 on CER1 was significant at the .05 level, while all the other 17 analyses were not significant. Of the 12 t-tests done, only two were significant at the .05 level for "target slide" number 15 on CER1 and on MCER.

Also, a comparison was done of "target slides" numbers 1 and 2 which appeared in most of the conditions. When either of these "target slides" appeared in the three different alternatives conditions (holding constant the number of choice points) a simple analysis of variance was done. Of the 18 analyses performed, only three for "target slides" number 2 on TTC, CER1 and MCER were significant at the .01 level. The other 15 analyses were not significant.

Second, when either "target slides" numbers 1 or 2 appeared in the three different choice points' conditions (holding constant the number of alternatives) an analysis of variance for repeated measures was done. This time H_2 was being tested. All the 18 analyses of variance done were significant: 13 at the .01 level and 5 at the .05 level. In all cases the 2-choice points' condition was easiest to process. In eight of the 18 cases the 5-choice points' condition was easier than the 4-choice points' condition.

Third, "target slides" numbers 1 and 2 were also compared within the two conditions yielding 16 combinations (four alternatives and 2-choice points versus two alternatives and 4-choice points). Each comparison involved a t-test with 22 degrees of freedom. According to H_1, the condition with more choice points should be more difficult to process. Of the 12 t-tests done, 10 were significant in the predicted direction, nine at the .05 level and one at the .01 level.

"Target slide" number one was also compared between the three alternatives and 5-choice points' condition and the four alternatives and 4-choice points' condition. The former condition was expected to be more difficult despite the fact that it yielded 243 combinations compared to the 256 combinations of the latter condition. Of the six t-tests done, only the one for PT1 was significant at the .05 level. In this case the hypothesis was not confirmed.

Experiment 2

The design of Experiment 2 also enabled several data analyses. It should be recalled that each subject was run in all six experimental conditions thus creating a correlated by correlated measure's design.

H_1 predicted that in situations of equal information in two stimuli, the stimulus with more choice points would be more difficult to process. H_2 states that the number of choice points will be directly related to the difficulty of processing given equal numbers of alternatives per choice point. Both H_1 and H_2 can be tested by the treatments X treatments X subjects (A X B X S) design of analysis of variance offered by Lindquist (1953, pages 237-8). The amount of choice points are considered to be the A variable and the amount of information are considered to be the B variable. The hypotheses in these analyses of variance would predict the main effects for both variables A and B to be significant while no interaction was expected. Tables 12-17 present the results of these analyses. It should be noted that in the case of TTC there is no meaning for H_2 (main effect B) since the dependent variable cannot be corrected for guessing and can, therefore, only be employed when the amount of uncertainty is kept constant. As for main effect A, however, TTC can be tested since the amount of information is in fact held constant.

Table 12. Means and analysis of variance for treatment X treatment X subject design for TTC--trials to criterion in Experiment 2.

Source	Sum of squares	Degrees of freedom	Mean square	F
A - Choice points	62.4222	1	62.4222	16.175*
B - Information	284.7444	2	142.3722	47.034*
S - Subjects	126.5778	29	4.3648	
A X B	1.8778	2	0.9389	0.233
A X S	111.9111	29	3.8590	
B X S	175.5889	58	3.0274	
A X B X S	233.7889	58	4.0308	
Total	996.9111	179		

*p<.001

Means

		Choice points		
		More	Fewer	Mean
Information level	16	2.27	1.23	1.75
	64	3.23	2.20	2.72
	256	5.50	4.03	4.77
	Mean	3.67	2.49	3.08

Table 13. Means and analysis of variance for treatment X treatment X subject design for CER1--corrected error-rate on first trial in Experiment 2.

Source	Sum of squares	Degrees of freedom	Mean square	F
A - Choice points	2.2851	1	2.2851	14.264*
B - Information	1.6272	2	0.8136	5.794**
S - Subjects	3.7999	29	0.1310	
A X B	1.0933	2	0.5467	4.377***
A X S	4.6448	29	0.1602	
B X S	8.1410	58	0.1404	
A X B X S	7.2422	58	0.1249	
Total	28.8336	179		

*p<.001
**p<.005
***p<.025

Means

		Choice points		
		More	Fewer	Mean
Information level	16	0.60	0.16	0.38
	64	0.61	0.47	0.54
	256	0.65	0.56	0.60
	Mean	0.62	0.40	0.51

Table 14. Means and analysis of variance for treatment X treatment X subject design for MCER--mean corrected error-rate per trial in Experiment 2.

Source	Sum of squares	Degrees of freedom	Mean square	F
A - Choice points	0.8556	1	0.8556	23.310*
B - Information	0.7177	2	0.3588	10.340*
S - Subjects	0.7631	29	0.0263	
A X B	0.3135	2	0.1568	4.272**
A X S	1.0656	29	0.0367	
B X S	2.0100	58	0.0347	
A X B X S	2.1804	58	0.0376	
Total	7.9059	179		

*p<.001
**p<.025

Means

		Choice points		
		More	Fewer	Mean
Information level	16	0.33	0.08	0.21
	64	0.34	0.25	0.29
	256	0.39	0.33	0.36
	Mean	0.36	0.22	0.29

Table 15. Means and analysis of variance for treatment X treatment X subject design for PT1--processing time on first trial in Experiment 2.

Source	Sum of squares	Degrees of freedom	Mean square	F
A - Choice points	11.1851	1	11.1851	2.301
B - Information	67.6032	2	33.8016	2.249
S - Subjects	1550.7161	29	53.4730	
A X B	6.0027	2	3.0013	0.651
A X S	140.9261	29	4.8595	
B X S	871.5175	58	15.0262	
A X B X S	267.5990	58	4.6138	
Total	2915.5497	179		

Table 15 (cont'd.)

		Choice points	
	More	Fewer	Mean
Information level, 16	4.69	3.73	4.21
64	4.98	4.91	4.94
256	5.94	5.48	5.71
Mean	5.20	4.70	4.95

Table 16. Means and analysis of variance for treatment X treatment X subject design for PTC--processing time on correct trial in Experiment 2.

Source	Sum of squares	Degrees of freedom	Mean square	F
A - Choice points	385.4127	1	385.4127	3.499
B - Information	703.9564	2	351.9782	3.134
S- Subjects	4378.0420	29	150.9670	
A X B	534.2405	2	267.1202	2.365
A X B	3193.4613	29	110.1194	
B X S	6512.9292	58	112.2919	
A X B X S	6549.9260	58	112.9298	
Total	22257.9681	179		

Means

		Choice points	
	More	Fewer	Mean
Information level' 16	4.65	3.47	4.06
64	5.09	5.24	5.17
256	12.57	4.83	8.70
Mean	7.44	4.51	5.97

Table 17. Means and analysis of variance for treatment X treatment X subject design for MPT--mean processing time on all trials in Experiment 2.

Source	Sum of squares	Degrees of freedom	Mean square	F
A - Choice points	13.2069	1	13.2069	4.033
B - Information	38.6065	2	19.3032	2.778
S - Subjects	1551.6804	29	53.5062	
A X B	1.7356	2	0.8678	0.154
A X S	94.9499	29	3.2741	
B X S	403.1380	58	6.9507	
A X B X S	325.3055	58	5.6087	
Total	2428.6227	179		

Means

		Choice points		
		More	Fewer	Mean
Information level	16	4.63	4.11	4.37
	64	5.00	4.69	4.85
	256	5.89	5.10	5.50
	Mean	5.17	4.63	4.90

The results indicate that H_1 and H_2 were confirmed only for TTC, CER1 and for MCER but not for the three processing time dependent variables (the significant main effect B for TTC should be disregarded as pointed out above). Furthermore, in the cases of the error rate measures there was also significant interaction.

H_3 predicted that given a constant number of choice points in a set of stimuli, the number of alternatives per choice point is directly related to the difficulty of processing the stimuli. This hypothesis was tested by comparing the two alternatives and 4-choice points' condition to the four alternatives and 4-choice points' condition.

The comparison was done by means of correlated t-tests and was performed on all dependent measures except for TTC. The number of degrees of freedom was 29 in each case. The results of the t-tests indicate that there were no significant differences between the two conditions in any of the dependent measures, the highest value of t being 0.97 and the lowest value being 0.14.

CHAPTER IV

DISCUSSION

Based on work done by Katzman (1970) this research is an attempt to establish the relative importance of the number of stimulus dimensions in human information processing. Information Theory has led to predictions that the amount of information contained in a stimulus is directly related to the difficulty of processing. The theory advanced here is that in stimuli containing equal amounts of information but differing in the number of dimensions and number of alternatives per dimension, the number of dimensions would be directly related to the difficulty of processing. In other words, it is hypothesized that the number of dimensions is a more crucial variable than the number of alternatives per dimension.

Two experiments were conducted to test this notion. The first experiment used various geometrical forms as stimuli, whereas the second experiment employed drawings of human male faces. The task in the first experiment had to do with identifying the various dimensions of the stimuli, while in the second the subjects were required to reconstruct the faces using the various features as dimensions. In both experiments the dependent variables were the number of trials to criterion, two measures of corrected error-rate and three measures of the time it took the subjects to organize their thoughts from the time of the appearance of the stimuli until the subject's attempt at a solution. In both experiments the stimuli were presented tachistoscopically.

Experiment 1

The analyses of variance for correlated measures (Tables 5-9) provide clear evidence for the support of the hypothesis indicating that, when holding constant the number of alternatives, the number of choice points will be directly related to the difficulty of processing. This holds true both for the error-rate measures and for the processing time measures. At the same time there is no support for the hypothesis (except on the Mean Corrected Error-Rate measure) which states that when holding constant the number of choice points, the number of alternatives will be directly related to the difficulty of processing. This latter hypothesis would be a direct test of the predictions made by adherents of Information Theory, thus, failing to support it while at the same time confirming the former hypothesis seems to lend even further support to the choice points' notion.

Upon a close look at the means in the tables, a curious fact appears. On all dependent variables there seems to be an appreciable difference in the predicted direction between the 2-choice points and the 4-choice points' conditions, holding alternatives constant. However, the differences between the 4-choice points and the 5-choice points' conditions are often negligible and at times even in the direction contrary to what had been predicted. Furthermore, this is mainly the case for the two and three alternatives' conditions on the three dependent variables dealing with processing time.

This fact seems to indicate that perhaps one of the following factors was operating. What was considered to be the fifth choice point, i.e., the direction of the triangle, was maybe not in fact viewed by the subjects as an additional choice point. There might have been what Garner (1970) calls "integrality of dimensions" so that the direction of the triangle and some other choice point (perhaps the color of the triangle) were viewed and processed by the subjects as a single choice point. Or, it might be that the fifth choice point was fine as such, but that the addition of only one choice point to the other four choice points was not a strong enough manipulation of the independent variables. It is really unfortunate that the experimental design did not have two, four and six choice points as had been planned and noted previously.

One of these explanations seems plausible when the analysis of the results for the main hypothesis is examined. Here it was predicted that when holding constant the amount of information in two stimuli, the one with the more choice points would be more difficult to process. This hypothesis is supported fully in the case involving two and four choice points at the level of 16 possible combinations (Table 10). However, it is not confirmed at all when dealing with four versus five choice points (Table 11). Once again the question of four versus five choice points arises with no way of proposing a clear-cut explanation other than the two that have been presented above.

Both proposed explanations continue to assume the validity of the choice points' notion and the "packaging" model. There is, of course, a third possibility that the theory is incorrect for higher levels of information, though it does seem to hold for relatively lower levels of information. In Katzman's research cited earlier in this paper there is no direct or indirect evidence to support the choice points' notion at higher levels of information, a fact which makes this study important. Furthermore, maybe at higher levels of information only very large differences in the number of choice points would support this theory, for example, when there are four versus eight choice points at the level of 256 possible combinations (4^4 and 2^8). However, if this were the case, some choice points by alternatives interaction should have been recorded in Experiment 1 but none was even close to being significant. Therefore, the only conclusion that can be advocated at this point is that the choice point notion is still valid and that probably one of the two explanations is sufficient to explain the slightly incomplete picture given by the data.

The additional results of Experiment 1 dealing with single stimuli which were presented in more than one experimental condition maintain a similar pattern. The choice points' hypothesis is supported throughout; the alternatives' hypothesis is supported in only four of the 36 comparisons; and the main hypothesis is supported 10 out of 12 times for the lower level of information but only once in six at the higher level of information.

One final point on the results of the first experiment seems worth mentioning. At the termination of each experimental session each subject was asked which condition was easiest and which was most difficult for him. All 36 subjects ranked the 4-choice points' condition as more difficult than the 2-choice points' condition while only 27 of the 36 ranked the 5-choice points' condition as the most difficult in the experiment. Here, too, this additional data seems to fit into the same general pattern.

Experiment 2

The interpretation of the results of Experiment 2 should be divided into two sections: one dealing with the error rate and trials to criterion measures and the other with the processing time measures. As for the error rate measures, both hypotheses testing the choice points' notion were analyzed in the correlated by correlated measures analyses of variance designs. Both hypotheses yielded significant results indicating clearly that the number of choice points is directly related to the difficulty of processing. Furthermore, the test of the alternative's hypothesis for the error-rate measures did not yield significant results, a fact which gives additional support to the importance of the choice points' notion. Not obtaining significant results for the alternatives' hypothesis does not mean that it is refuted, but only that it cannot be supported by the data, whereas the choice points' hypotheses were indeed supported.

However, in Experiment 2, the analyses of variance also yielded significant choice points by information levels interaction which required a careful examination of the cell means. As Figures 3a and 3b illustrate, the greatest difference between the "more choice points" and "fewer choice points'" conditions occur at the lowest level of information (16 possible combinations) whereas at the two higher levels the differences are rather slight. Tests for the significance of the differences between the "more choice points" and "fewer choice points'"

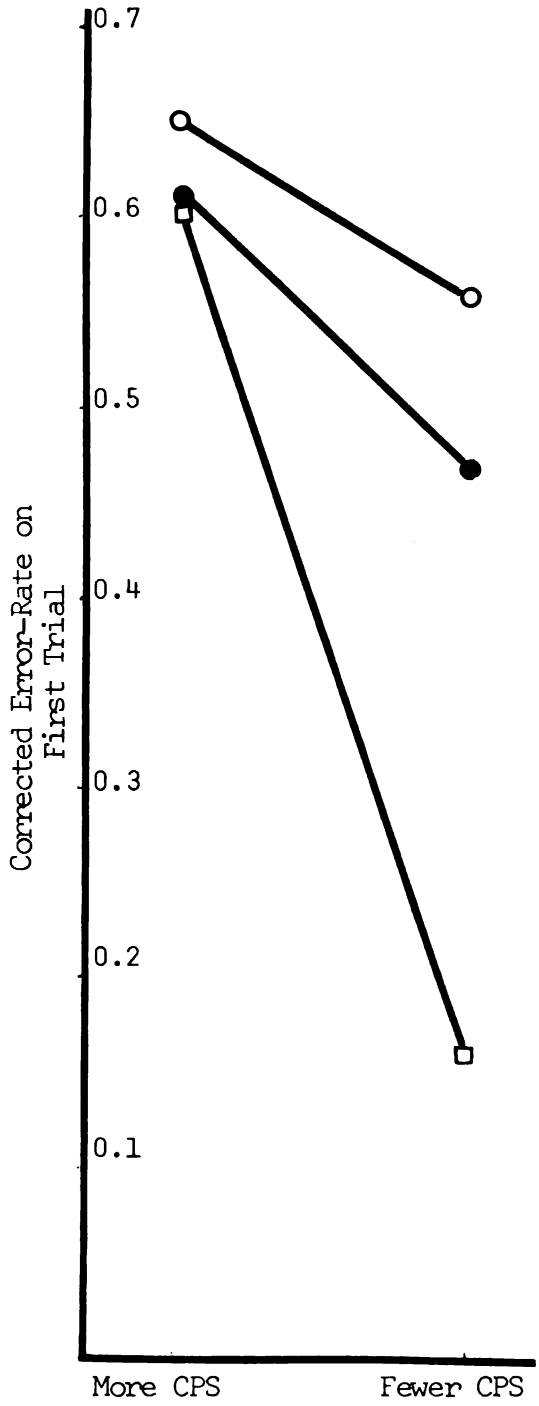

Figure 3a. The corrected error-rate on the first trial for each level of information and choice points.

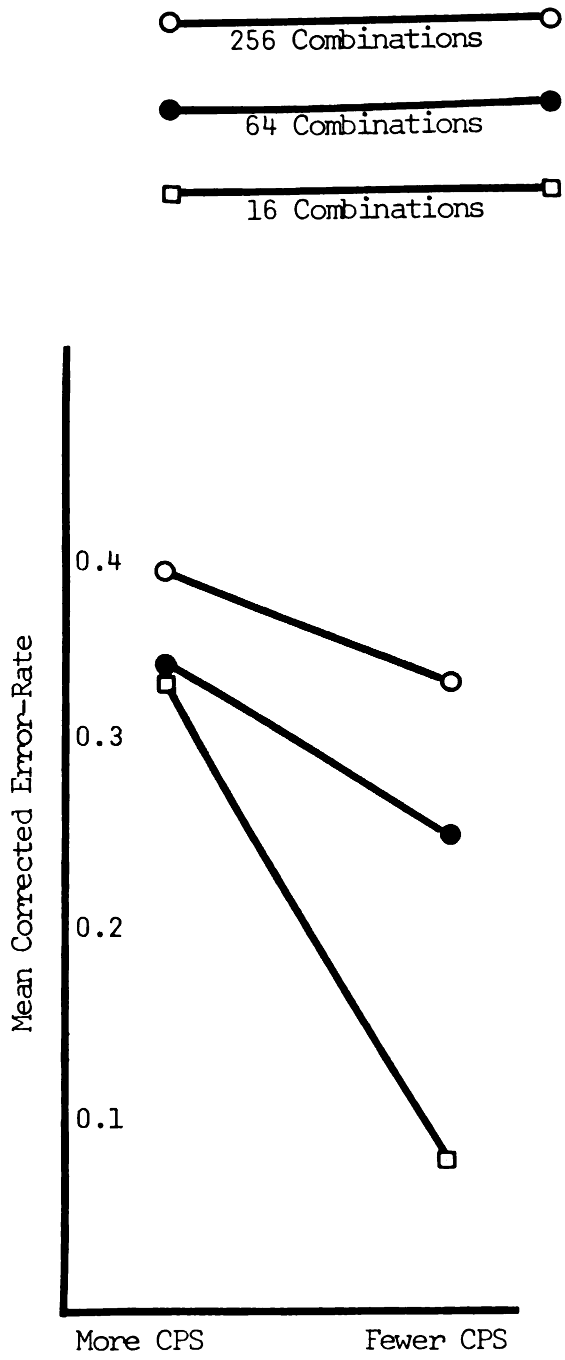

Figure 3b. The mean corrected error-rate for each level of information and choice points.

conditions for each level of information were done on the error-rate measures using one-tailed t-tests for correlated measures (the number of degrees of freedom was 29). At the level of 16 possible combinations the 2^4 condition is significantly higher than the 4^2 condition for both measures.*

At this point the test of the main choice point hypothesis for the Trials to Criterion measure should be mentioned. It yielded significant results in the expected direction. The other two hypotheses do not have meaning for that measure as noted above. At any rate, the Trials to Criterion measure gives some additional support to the choice points' notion.

As for the processing time measures, no significance was reached for any of the three hypotheses tested. The position taken here is that the measures themselves were quite insensitive in Experiment 2, the reason for which may become clear when the facial construction strategies of the subjects are reviewed.

At the termination of the experiment the subjects were asked how they went about reconstructing the faces. It should be recalled that the subjects were presented at one time with all the alternatives of the facial features considered relevant. It turned out that the subjects used different strategies. Some began with an attempt to reconstruct the face by remembering the various features (choice point by choice point in a sequential manner) while others reported attempting to remember the

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*$t_{CER1}=3.85$ ($p<.01$) and $t_{MCER}=4.51$ ($p<.01$); at the level of 64 possible combinations $t_{CER1}=1.48$ (n.s.) while $t_{MCER}=1.82$ ($p<.05$); at the level of 256 possible combinations $t_{CER1}=1.28$ (n.s.) and $t_{MCER}=1.61$ (n.s.).

face as a gestalt and process all the choice points in a parallel manner. In addition, most of the subjects changed their strategies at least once during the experiment (sometimes even on subsequent trials of the same face). It seems that the two strategies may have required different amounts of time and that changing the strategy within a given face also took extra time, thus resulting in a poor dependent variable. This problem did not occur in Experiment 1 where it is presumed that due to the manner in which the choice points were presented, the subjects had to relate to each choice point in a sequential manner and they knew each time what choice point was coming up for their decision.

The only other plausible explanation for lack of differences could be that in Experiment 2 there was also some degree of "integrality of dimensions," but this idea must be rejected in light of the findings on the error-rate measures and the fact that the subjects claimed that the task was harder for them the more features they had to deal with.

In the discussion of Experiment 1 reference was made to the possibility that in high levels of information large differences are needed in the number of choice points in order to get the predicted effect of choice points. Experiment 2 provided this exact opportunity with the 4^4 versus 2^8 situation, and as has been pointed out, in that case the smallest differences were obtained. This fact leads back to the speculations made concerning the validity of the choice points' notion and packaging model at high levels of information. Even if it were conceded that both experimental designs suffered from "integrality of dimensions," nevertheless there are signs to indicate that perhaps at higher levels of information the number of choice points ceases to be the crucial factor responsible for the ease or difficulty of information processing.

The research reported here by Siegel and by Katzman did not reach high levels of information. The two experiments in this paper do confirm previous findings for low levels of information but raise serious doubts as to the relative importance of choice points at high levels of information. More research is definitely needed to test this theory and more stringent controls must be taken to exclude any possibility of dimensional integrality, and thereby enabling a clear-cut test.

At this point in the paper mention must be made of defects in the designs. In Experiment 1 it is unfortunate that the sixth choice point, that of the type of border of the external geometrical form, could not be used. This difficulty resulted in a weaker manipulation of the choice points variable. Another flaw was the faulty planning for the comparisons between different experimental conditions of those stimuli that appeared in more than one condition. However, in retrospect, it seems that this created superfluous anxiety since many comparisons were in fact made yielding favorable results. As for Experiment 2, perhaps it would have been better had each subject received two different faces in each experimental condition. But, as noted earlier, it was felt that too long an experimental session was also undersirable.

The rather unique processing time dependent measures were used instead of the more widely employed reaction time measures. This type of measure was used since it was presumed that the subject would require extra time to process the stimuli beyond the brief exposure time, and thus this processing time could be tapped. It was also assumed that the more choice points contained in the stimuli, the more time it ought to take to be processed. These measures seemed to operate well in Experiment 1, but due to frequent changes in the subjects' strategies in Experiment 2 the measures became insensitive to what was being tapped, i.e., processing time.

Implications

The question of the relevance of this research to the study of human communication might naturally arise, especially since this realm of research has been traditionally in the hands of psychologists. It is felt that communication scholars should be interested in this area for several reasons. Information is one of communication's basic concepts. Recent models of the communication process include the level of uncertainty and of information (e.g. Berlo). Information can be viewed as a commodity. As such, people try to gain information, process it, store it and use it. The question is, how do people process and store information? Psychologists are concerned with the organism's capacity to process information in terms of quantities and limits. Communication researchers should be concerned with this question and others: how is information stored? what form does it take? how is it retrieved? how is it used?

If indeed information is processed in chunks, as the packaging model suggests, then this ought to be important in the preparation of messages used in communication of various sorts. Packages of information should be constructed keeping in mind their optimal sizes. For example, questionnaires should be designed and written with this idea in mind so that a respondent can handle the information presented to him for his comments. Programmed instruction materials should be prepared so as to get the greatest possible amount of information into the fewest possible choice points. These are only two of the possible applications of these findings to communication.

It still remains to be seen whether choice points are as crucial in processing situations containing large amounts of information as they are in situations containing relatively little information. Some of the doubts expressed here will hopefully encourage further research in an attempt to reach a more conclusive answer.

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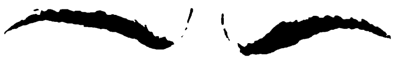
APPENDIX

An example of the facial features
used in Experiment 2
(Compare with Figure 2)

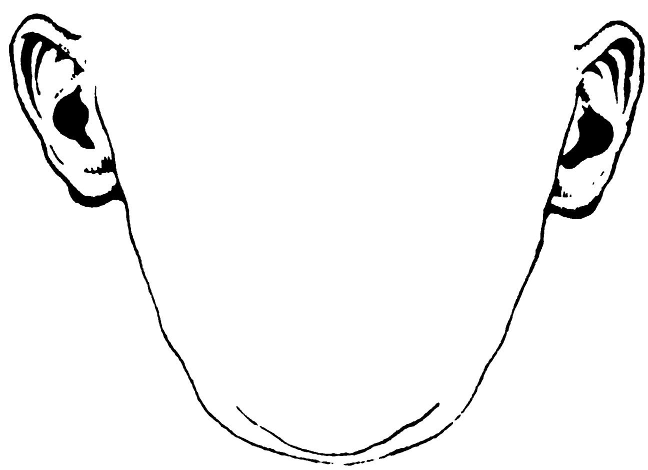
Eyebrows



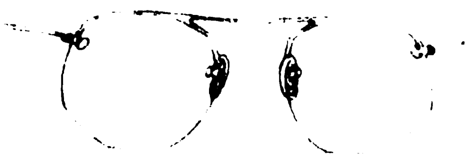
Nose

Hair

Ear-chin combination



Glasses

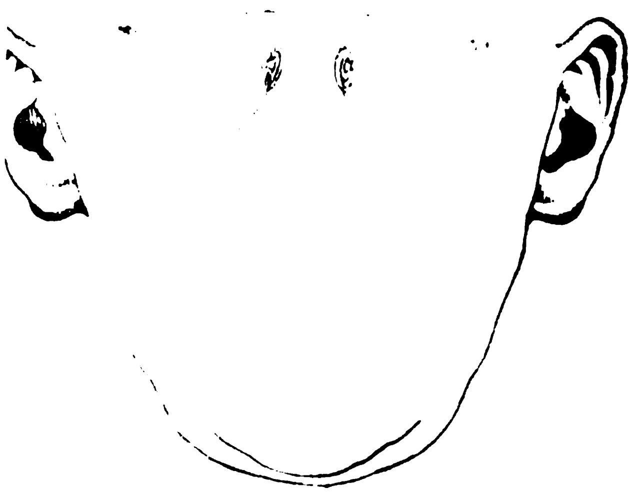


Eyes

Mouth

Mustache

Frame with 2-choice points



Frame with 4-choice points

Frame with 5-choice points

Frame with 6-choice points