Task Complexity and Contingent Processing in Decision Making: An Information Search and Protocol Analysis

JOHN W. PAYNE

Carnegie-Mellon University

Two process tracing techniques, explicit information search and verbal protocols, were used to examine the information processing strategies subjects use in reaching a decision. Subjects indicated preferences among apartments. The number of alternatives available and number of dimensions of information available was varied across sets of apartments. When faced with a two alternative situation, the subjects employed search strategies consistent with a compensatory decision process. In contrast, when faced with a more complex (multialternative) decision task, the subjects employed decision strategies designed to eliminate some of the available alternatives as quickly as possible and on the basis of a limited amount of information search and evaluation. The results demonstrate that the information processing leading to choice will vary as a function of task complexity. An integration of research in decision behavior with the methodology and theory of more established areas of cognitive psychology, such as human problem solving, is advocated.

The problem of preferential choice is an old one in psychology. Many years of research effort have been devoted to developing various mathematical models which could describe decision behavior. Unfortunately, these attempts to develop a general model of decision making have proved frustrating. All of the models proposed have received some empirical support, but none seems completely satisfactory as an explanatory model. The present paper suggests an alternative approach to understanding decision behavior. The approach derives from research on human problem solving (cf. Newell & Simon, 1972) which has made it clear that in performing complex tasks individuals utilize different heuristics that will keep the information processing demands of the situation within the bounds of their limited capacity. Preferential choice among multidimensional alternatives would seem sufficiently complex to require the same general type of heuristic processing. Research on problem solving has

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Requests for reprints should be sent to John W. Payne, who is now at the Graduate School of Business, University of Chicago, Chicago, IL 60637.

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also shown individual behavior to be highly adaptive to the demands of the task. This suggests that the heuristics used by decision makers may be systematically related to certain characteristics of the decision situation. The research reported in the present paper represents an initial attempt to identify those task characteristics which push an individual towards various decision strategies.

**Models of Decision Making**

In this section of the paper we will briefly examine four of the most important decision models which have been proposed in terms of their underlying process assumptions. That is, what do each of the models imply about the information processing which would precede a final choice. Newell (1968) points to this emphasis on how a particular decision came about as one important characteristic of the representation of human behavior as an information processing system.

Perhaps the earliest rule of decision making to be proposed is the additive or linear model of choice. With an additive model, the process of choosing among multidimensional alternatives is assumed to proceed as follows: Each alternative in a choice set is evaluated separately. A value, either objective or subjective, is arrived at for each component, or dimension, of an alternative. The components are then combined in an additive fashion resulting in an overall value for that alternative. Comparisons are then made among the overall values of the alternatives and the one with the greatest value is chosen. An important aspect of the additive model is that it is compensatory. That is, the additive model implies that a decision maker will trade-off between a high value on one dimension of an alternative and a low value on another dimension.

While the results of most studies of the linear model have been generally supportive (Slovic & Lichtenstein, 1971), a concern with the cognitive aspects of decision theory has led some researchers to propose models of choice which they argue would reduce the information processing demands being made on the individual. An early example of this type of model was Simon's (1957) principle of *Satisficing*. Simon argued for a model of "rational" choice where a decision maker would search the space of alternatives only until he found an alternative that exceeded some minimum aspiration level. A similar nonlinear, noncompensatory decision rule has been suggested by a number of researchers (Coombs, 1964; Dawes, 1964; Einhorn, 1970). The model proposed is called the conjunctive model. The model implies that whether a multidimensional alternative $x = (x_1, x_2, \ldots, x_n)$ surpasses some stimulus or standard $y = (y_1, y_2, \ldots, y_n)$ will depend on $x_i$ being greater than $y_i$ for all $i$. In other words, an alternative must have a certain minimum value on all the relevant dimensions in order to be chosen.
Exactly how the set of information processes implied by the conjunctive and satisficing models would deal with a decision situation involving choice among a limited and well defined set of alternatives is not completely clear. One possible procedure would be to use a satisficing criterion to eliminate alternatives. By varying the aspiration level, a decision maker could make repeated evaluations of the alternatives in a choice set until only a single alternative remained. That alternative would then be the preferred alternative.

Tversky (1969) proposed the additive difference model which, unlike the additive and conjunctive models, assumes that decision makers use an intradimensional evaluation strategy. In that type of processing strategy the alternatives are compared directly on each dimension, a difference is determined, and the results are summed together to reach a decision. Since the additive difference model is based on a direct comparison between two alternatives, there is a question of how such a decision strategy would work in a multialternative choice situation. One solution for a decision maker would be to compare a given alternative to only the best of the preceding alternatives. If the given alternative is preferred, it can become the new standard against which each of the remaining alternatives will be compared.

The final theory of choice to be discussed was presented by Tversky (1972), and is called the elimination-by-aspects (EBA) model. The model describes choice as a covert elimination process. In choosing among multidimensional alternatives the individual is assumed to proceed in the following manner. A dimension or aspect is selected. Then all the alternatives that do not possess that dimension or aspect are eliminated. The procedure is repeated until all but one of the alternatives is eliminated. The probability of selecting an aspect or dimension is assumed to be proportional to its weight or relative importance. Notice that the EBA model, like the additive difference model, implies an intradimensional evaluation strategy.

Process Tracing and Decision Models

Part of the difficulty in developing a complete explanatory model of decision behavior arises from the empirical procedures which have typically been employed. Most research on decision behavior has focused on data which reflect only the end product of the decision process, e.g., choice proportions, rankings, or ratings. In contrast, the present study will use two methods of experimentation which should provide valuable insights into the information processing strategies which led a subject to exhibit a particular choice.

The first experimental procedure will involve presenting subjects with decision tasks where they will have to search for information about the
alternatives available. Examination of a subject’s pattern of information search should provide a method for discriminating between alternative models of decision making in terms of the information processing behavior assumed to underlie the various models. Each of the four models of decision making discussed earlier, additive, additive difference, conjunctive, and elimination-by-aspects, imply, at least in their most common forms, different information search processes.

Two characteristics of the search patterns will be of primary interest. The first characteristic deals with the percentage of available information searched on each alternative in a choice set. In particular, we will be interested in whether a decision maker searches a constant or variable amount of information across the alternatives. The second characteristic concerns whether the decision maker uses an interdimensional or an intradimensional search strategy. Each model may be seen in terms of a particular combination of these two search characteristics.

An additive decision strategy would imply an interdimensional and constant pattern of search. A decision maker following a strict additive difference model would have to search a constant amount of information per alternative, but would search in an intradimensional fashion. Both the conjunctive and EBA models, on the other hand, imply the possibility of a decision maker using a variable search pattern. That is, these two models imply a limited search strategy which would involve a minimum of one dimension up to all the relevant dimensions of an alternative. The preferred alternative would be evaluated on the maximum number of dimensions. The conjunctive and EBA models differ, however, in whether they imply an interdimensional (conjunctive) or intradimensional (EBA) search strategy.

The second research procedure will involve asking subjects to “think aloud” while actually making their decisions. This procedure should provide data which will supplement the information search findings. While answers to the question “What are you doing right now?” may be misleading, they are likely to be considerably less misleading than later descriptions of how the task was performed. When combined with objective evidence of what the decision maker is doing, e.g., search data, information may be obtained from verbal reports elicited during the decision making performance which would otherwise be lacking. Verbal protocols have proved valuable in other areas of cognitive psychology (Newell & Simon, 1972) and decision making (Clarkson, 1962; Braunstein & Coleman, 1967; Payne, 1974; Soelberg, 1965; Svenson, 1974).

Contingent Decision Making and Task Complexity

The four models of decision behavior reviewed in this paper have often been discussed as competing general models of choice. In contrast, the
present paper, consistent with research on human problem solving (cf. Newell & Simon, 1972), views the models as complementary. That is, a given decision maker might employ both compensatory and noncompensatory choice processes contingent upon the demands of the decision task. The present study will investigate the choice strategies used by individuals as a function of the two task determinants: number of alternatives available and number of dimensions of information available per alternative.

It is surprising that relatively few studies have investigated the effects of these task determinants on choice behavior. The general theoretical approach seems to have been to postulate a general model of choice which would be applicable to a choice situation regardless of the number of alternatives (Corbin & Marley, 1974; Luce, 1959; Restle, 1961; Tversky, 1972). Empirical studies of multialternative choice have been almost entirely lacking. Most research on human decision behavior has concentrated on the problem of how people choose the better of two alternatives. Two recent exceptions are studies by Russo and Rosen (1975) and Wright (1975). Russo and Rosen investigated choice among six alternatives. Their principal finding was that multialternative choice process consists primarily of binary comparisons. However, as Russo and Rosen point out, the generality of their finding would seem to be limited to choice sets of intermediate size, at best.

There have been a few more studies aimed at investigating the effect of amount of information available on judgment behavior (Hayes, 1964; Hendrick, Mills, & Kiesler, 1968; Einhorn, 1971; Jacoby, Speller, & Kohn, 1974). In general, the results from these studies seem to indicate that the effects of increasing the amount of information are to increase the variability of the responses and to decrease the quality of the choices while also increasing the confidence of a decision maker in his judgments (Slovic & Lichtenstein, 1971).

In summary, the present study will use two process tracing techniques: (1) explicit information search and (2) verbal protocols, to make explicit the effects of two variations in the complexity of a decision task, (a) number of alternatives and (b) number of dimensions, on the information processing strategies subjects use in reaching a preferential choice.

**EXPERIMENT 1**

**Method**

**Subjects.** There were six subjects who were paid at a fixed hourly rate for their participation in the experiment. The subjects were all of college age. They were naive with respect to the task and stimuli.

**Stimuli.** The stimuli were "information boards" (Wilkins, 1967) representing different one-bedroom furnished apartments. An information
board consisted of a number of envelopes attached to 20 in. \(\times\) 6\(\frac{3}{4}\) in. sheet of cardboard. The envelopes contained 4 in. \(\times\) 6 in. cards labeled with the name of a dimension of information, e.g., "noise level." To obtain the value of that dimension for a particular alternative, the subject had to pull the card out of the envelope, turn it around and place it back into the envelope. The information about the value of the dimension was on the back of the card, e.g., "Noise level—low." Once a card was turned over, the value of the dimension on the particular alternative was clearly displayed for the remainder of the choice problem.

A decision situation for a subject involved a number of alternatives, either 2, 6, or 12, and a number of dimensions of information available per alternative, either 4, 8, or 12. Each subject received three of the nine possible combinations of number of alternatives with number of dimensions per alternative. The three combinations received by a subject contained some combination of the three levels of the number of alternatives variable and the three levels of the amount of information variable. The order of presentation of the decision situations was counterbalanced across subjects.

There were three levels of value on each dimension. Some of the dimension values were expressed as quantitative values, e.g., rent—$110, $140, or $170, and some were expressed more qualitatively, e.g., noise level—low, moderate, or high. The values of an alternative on the various dimensions were chosen such that no alternative would completely dominate another on all the available dimensions. The dimensional values were selected so that each alternative would have a priori both good and poor qualities.

Each increase in the number of dimensions of information available per alternative contained the previous available dimensions as a subset. That is, an increase from four to eight dimensions per alternative involved just adding four additional dimensions to the original four. The reason for this procedure was to ensure that even the most limited information condition would involve at least some dimensions which would seem necessary to making a realistic choice, e.g., rent. This did not mean, however, that the added dimensions were necessarily of small importance. The values of the dimensions were varied across decision situations. The names of the dimensions and the values for the two-alternative, 12 dimension choice situations are given in Table 1. The alternatives were labeled A, B, . . . , L.

Procedure. Each subject was run individually in a 1-hr session. The subjects were told that they would be presented with a number of alternatives to choose among and a certain amount of information about each alternative. They were told that each alternative represented a furnished one bedroom apartment and that they should choose the apartment they would prefer for themselves on the basis of the information provided
TABLE 1
DIMENSIONS AND VALUES FOR THE TWO-ALTERNATIVE, 12-DIMENSION CHOICE SITUATION

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Low</td>
<td>Small</td>
<td>Fair</td>
<td>20 min</td>
<td>$110</td>
<td>Fair</td>
<td>Average</td>
</tr>
<tr>
<td>B</td>
<td>High</td>
<td>Moderate</td>
<td>Good</td>
<td>30 min</td>
<td>$170</td>
<td>Good</td>
<td>Below average</td>
</tr>
<tr>
<td>Alternatives</td>
<td>VIII</td>
<td>IX</td>
<td>X</td>
<td>XI</td>
<td>XII</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Poor</td>
<td>Good</td>
<td>Below average</td>
<td>Garage</td>
<td>Poor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Good</td>
<td>Fair</td>
<td>Average</td>
<td>Off street</td>
<td>Good</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a During the experiment the names of the dimensions were given on 4 × 6 cards.
b The number below in parentheses represents the lowest amount of information condition which included that dimension. I: Noise Level (4), II: Size, Living & Dining Rms. (4), III: Cleanliness (8), IV: Distance from Campus (8), V: Rent (4), VI: Brightness of Rms. (12), VII: Closet Space (12), VIII: Landlord Attitude (12), IX: Transportation Facilities (12), X: Furniture Quality (8), XI: Parking (8), XII: Kitchen Facilities (4).

about each apartment. A sample information board was shown to the subject. The subject was not instructed on how much of the available information he or she had to use in making the decision. If any subject specifically asked about information use they were told they were free to look at as little or as much information as they wanted to or felt was necessary to make a decision. No time constraints were placed on the subject. They were instructed to work at their own pace and that they should have plenty of time to finish.

The following “think aloud” instructions were given to the subjects: “Whenever you start to look at a piece of information, say what you’re going to look at. When making an observation about an apartment on the basis of a piece of information, describe each conclusion and the specific observations which you are using to support your judgment. Finally, please state aloud the line of reasoning you are using to go from the observations to your decision.”

The subject was asked if he or she had any questions and then was presented with the first set of choice alternatives. The subject was allowed to rest briefly after making his or her choice and then a new set of alternatives was presented. The procedure was then repeated for a third time.

During the experiment a record was kept by the experimenter of the order in which information was examined by each subject in each decision situation. For example, if the first 4 × 6 card a subject turned over was the rent of apartment A, that piece of information was assigned a value of 1; the second card examined was then given the value 2, and so on. The
search results are based on this objective record of the pattern of information search exhibited by each subject in each decision situation. The verbal protocols provide information about repeated observations of the same piece of information.

Results

A complete transcript of the verbal reports given by each subject was made. Consistent with the procedure suggested by Newell and Simon (1972), the protocols were broken up into short phrases. The phrases were labeled, for example, A1, A2, . . . , A467. Each phrase was a naive assessment of what constituted a single task assertion or reference by the subject. Newell and Simon (1972) have argued that breaking verbal protocols up into small phrases "goes a long way towards isolating a series of unambiguous 'measurements' of what information the subject had at particular times (p. 166)."

During the analysis of the results, excerpts from the protocols of the six subjects will be presented. Unfortunately, space limitations make it impossible to reproduce the complete protocol for each subject in this report. The complete protocols for the six subjects may be obtained from the author.

The search data for each subject is primarily organized in terms of the amount of available information searched and pattern of search, interdimensional or intradimensional. Table 2 presents the mean percentage of available information searched for each subject and treatment combination (number of alternatives and number of dimensions per alternative). The standard deviation of the percentage of information search is also given. This statistic measures the variability in the amount of information searched per alternative in a particular choice situation. Notice that the percentage of information searched declined both as the number of alternatives available in a decision situation increased and as the number of dimensions per alternative increased.

The interesting question concerns how the subjects went about the process of reducing the mean percentage of information searched. An answer to this question is provided, in part, by examining the amount of variation in information searched across the alternatives for each subject in each treatment combination. When the subjects were asked to choose between just two alternatives, they always searched the same amount of information on each alternative. For Subjects 1, 2, 3, and 4, this included all available information. Subjects 5 and 6 did not search all the information before making a choice. However, like the first four subjects, they also searched the same amount of information on both alternatives. Such a search pattern is consistent with a compensatory decision rule such as an additive process or additive difference process.
TABLE 2

MEAN PERCENTAGE OF AVAILABLE INFORMATION SEARCHED FOR EACH SUBJECT AND TREATMENT COMBINATION

<table>
<thead>
<tr>
<th>Number of alternatives&lt;sup&gt;a&lt;/sup&gt;</th>
<th>2</th>
<th>6</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>4</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>1</td>
<td>1.0</td>
<td>.542</td>
<td>.708</td>
</tr>
<tr>
<td></td>
<td>(0)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>(.240)</td>
<td>(.123)</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
<td>.792</td>
<td>.368</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(.246)</td>
<td>(.290)</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
<td>.563</td>
<td>.563</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(.220)</td>
<td>(.285)</td>
</tr>
<tr>
<td>4</td>
<td>1.0</td>
<td>.500</td>
<td>.472</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(.403)</td>
<td>(.407)</td>
</tr>
<tr>
<td>5</td>
<td>.083</td>
<td>.500</td>
<td>.260</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(.224)</td>
<td>(.164)</td>
</tr>
<tr>
<td>6</td>
<td>.750</td>
<td>.611</td>
<td>.667</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(.146)</td>
<td>(.343)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Mean: 2—alternative, .806; 6—alternative, .582; 12—alternative, .506; 4—dimension, .754; 8—dimension, .630; 12—dimension, .510.

<sup>b</sup> Numbers in parentheses indicate the standard deviation of the percentage of information searched.

In contrast, consider the multialternative choice situations (6 or 12 alternatives). In these decision situations, all six subjects utilized a search procedure which resulted in a greater number of dimensions of information examined for some alternatives than for others in the same set of choice alternatives. Such a search pattern is compatible with the hypothesis that the subjects were using a noncompensatory decision rule such as an elimination-by-aspects process or a conjunctive choice process. For 11 of the 12 multialternative decision situations (2 for each subject), the amount of available information searched was as great or greater for the alternative chosen than for any other alternative in the choice set. In the remaining situation, the preferred alternative had the next to the maximum amount of information searched.

These results suggest that subjects may have been reducing the amount of information they had to search in the multialternative choice situations by eliminating some alternatives on the basis of only a few dimensions. An examination of the verbal protocols supports this view. For example, consider this excerpt from the protocol of Subject 1:

A162: Apartment E.
A163: The rent for apartment E is $140.
A164: Which is a good note.
A165: The noise level for this apartment is high.
A166: That would almost deter me right there.
A167: Ah, I don't like a lot of noise.
A168: And, if it's high, it must be pretty bad.
A169: Which means, you couldn't sleep.
A170: I would just put that one aside right there. I wouldn't look any further than that.
A171: Even though, the rent is good.

This subject appears to be using a conjunctive rule to eliminate alternatives on the basis of partial information about that alternative. The conjunctive rule is implied by the interdimensional pattern of search exhibited by this subject. Another explicit example of the elimination of alternatives after a limited search and evaluation is provided by this excerpt from the protocol of Subject 4:

D289: Since we have a whole bunch here,
D290: I'm going to go across the top and
D291: see which noise levels are high.
D292: If there are any high ones,
D293: I'll reject them immediately.

D297: Go to D.
D298: It has a high noise level.
D299: So, we'll automatically eliminate D.

D305: So, we have four here
D306: that are O.K. in noise level.

There are two important things to recognize in the excerpt from Subject 4. First, this subject seems to be using an intradimensional search strategy as part of the process of eliminating alternatives. Such a search strategy is consistent with an elimination-by-aspects process. Second, statement D289 is evidence that Subject 4 was developing a decision strategy determined, at least in part, by the fact that the decision situation involved a "whole bunch" of alternatives.

Additional support for the hypothesis that decision makers will vary their information processing rules as a function of task complexity may be seen in the following brief excerpt from the protocol of Subject 3. This excerpt deals with a decision problem involving six alternatives and eight dimensions of information.
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C98: Well, with these many apartments to choose from;
C99: I'm not going to work through all of the characteristics.
C100: Start eliminating them as soon as possible.

Table 3 presents the information search pattern exhibited by each subject in the different decision situations. The patterns of search have been classified into one of four categories depending on whether the search pattern was variable or constant in amount of information search per alternative, and whether the pattern of search was primarily across the dimensions and within a particular alternative or within a particular dimensions and across alternatives.

The pattern of search was determined, in part, by examining the alternative and dimension associated with the nth + 1 piece of information searched by a subject as a function of the alternative and dimension associated with the nth piece of information searched. If the nth + 1 piece of information searched was within the same alternative but involved a different dimension, then that constituted an instance of an interdimensional pattern of search. On the other hand, if the nth + 1 piece of information searched was within the same dimension, but a different alternative, then that constituted an instance of an intradimensional pattern of search. If the nth + 1 piece of information searched was neither within the same alternative or the same dimension as the nth piece of information, then that was considered to be a shift in the pattern of information search. In no case were there more instances of shifts in information search than instances of either interdimensional or intradimensional patterns of search. The number of instances of interdimensional, intradimensional, and shifts of information search for each subject and decision situation is given in Table 3. A measure of interdimensional v intradimensional search is given by the number of interdimensional singlestep transitions minus the number of intradimensional singlestep transitions divided by the sum of the two numbers. A pattern consisting of only interdimensional transitions and shift transitions, would have a value of +1.00. A pattern consisting of only intradimensional transitions and shifts, would have a value of −1.00. The mean value for the seven search patterns classified as interdimensional (see Table 3) was .808. The mean value for the seven search patterns classified as intradimensional was −.832. The mean for the four search patterns classified as mixed was −.097.

It has already been mentioned that all the subjects used a decision process which involved a constant amount of search per alternative when they were faced with a two-alternative choice situation. It has also been mentioned that such a search strategy is consistent with a compensatory decision process. The type of compensatory strategy employed, however, clearly varied between subjects (see Table 3). Two subjects used interdimensional search strategies in the two-alternative choice situations
### TABLE 3
CLASSIFICATION OF SEARCH PATTERNS

<table>
<thead>
<tr>
<th>Task characteristics</th>
<th>Number of alternatives</th>
<th>Number of dimensions</th>
<th>Interdimensional</th>
<th>Intradimensional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Constant</td>
<td>Variable</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>Subject 1 (6–0–1)</td>
<td>Subject 4 (0–4–3)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>Subject 6 (8–1–2)</td>
<td>Subject 2 (1–8–6)</td>
<td>Subject 3 (0–12–11)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&amp; Subject 5 (0–1–0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>Subject 5 (4–4–3)</td>
<td>Subject 2 (1–11–6)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Subject 3 (4–19–3)</td>
<td>Subject 4 (10–9–4)</td>
<td>Subject 6 (14–15–14)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&amp; Subject 4 (10–9–4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>Subject 1 (31–1–6)</td>
<td>Subject 3 (7–13–6)</td>
<td>Subject 6 (11–14–6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&amp; Subject 5 (10–7–7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&amp; Subject 4 (52–8–7)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- The numbers in parentheses are the number of instances of interdimensional, intradimensional, and shifts of information search, respectively, for each subject and decision situation.
- This subject only examined one piece of information per alternative, i.e., rent, in choosing among the two alternatives.
- A mixed search strategy which initially involved intradimensional search and which ended with interdimensional search.
which suggests that they were using an additive decision process. A clear example of the type of tradeoff analysis implied by an additive model may be seen in the following excerpt from the verbal protocol of Subject 1:

A24: O.K., the decision now is between the two rent prices
A25: in accordance with the other qualities.
A26: Now for apartment A has the advantage,
A27: because the noise level is low
A28: and the kitchen facilities are good
A29: even though the rent is $30 higher than B.

For this subject, the good values on the dimensions of noise level and kitchen facilities were seen to compensate for the higher rent price.

The other four subjects used an intradimensional search strategy. Such a search strategy, along with the constant amount of search per alternative, suggests that these subjects employed an additive difference decision process when faced with a two-alternative choice situation. The following excerpt from the protocol of Subject 4 is an example of a subject using a compensatory decision process and an intradimensional search procedure to choose among two alternatives:

D238: O.K., we have an A and a B.
D239: First look at the rent for both of them.
D240: The rent for A is $170 and
D241: The rent for B is $140.
D242: $170 is a little steep,
D243: but it might have a low noise level.
D244: So we'll check A's noise level.
D245: A's noise level is low.
D246: We'll go to B's noise level.
D247: It's high.
D248: Gee, I can't really very well study with a lot of noise.
D249: So I'll ask myself the question, is it worth spending that extra $30 a month for,
D250: to be able to study in my apartment.

Subjects in this experiment were clearly aware of compensatory decision processes and would clearly use such processes under certain task conditions.

It is also clear from the search data and from the verbal protocols that important individual differences do exist in the information processing which underlie decisions.

The final protocol excerpts which we will discuss are from Subject 2 and provide very clear data about that subject's decision processes in a 12-alternative choice situation. The first excerpt comes from an intermediate stage in the decision process. The excerpt shows the subject using both an intradimensional search pattern and an elimination rule:
B119: I'm going to look at landlord attitude.
B120: In H it's fair.
B121: In D it's poor.
B122: B it's fair, and
B123: A it's good.
B124: In L the attitude is poor.
B125: In K it's poor.
B126: In J it's good, and
B127: In I it's poor.
B128: So, one of them . . . is poor.
B129: So, that's important to me.
B130: So . . . that I'm living there,
B131: Which is the landlord also.
B132: So, I'm not going to live any place where it's poor.

After statement B132, the subject never again examined alternatives, D, I, K, and L.

The subject continues to search and evaluate alternatives until she is able to reduce the choice problem to a decision between just two alternatives. This subject was clearly using a strict elimination-by-aspects process to eliminate alternatives. A detailed analysis of the singlestep transition data showed that the subject was not only employing a variable and intradimensional search pattern but that all (remaining) alternatives were completely searched on one dimension before some subset of those alternatives were searched on the next dimension. This occurred on all eight dimensions which were examined by the subject in the process of reducing the choice set from 12 to 2 alternatives. Subject 3 in a six-alternative and eight dimension decision situation also appeared to use a pure elimination-by-aspects procedure.

The next excerpt is important in showing the subject shifting from an elimination-by-aspects procedure to what appears to be an additive difference strategy.

B172: So, eliminate those two (A & B)
B173: And decide between these two (J & H)
B174: O.K., the kitchen facilities in H are good.
B175: In J they're fair.
B176: And that's about the same to me.

B186: Landlord attitude in J is better than in H.
B187: And, that's important.

1 I wish to thank a reviewer for suggesting this additional analysis of the search data.
Notice that in directly comparing the final two choice alternatives the subject compares the two alternatives on previously examined dimensions, for example, landlord attitude (B186), and also seeks information about a new dimension and makes a comparison (B190–B193).

EXPERIMENT 2

The purpose of this experiment was to further examine the generality of the hypothesis that the information processing leading to choice is contingent on task complexity. This experiment used stimuli and procedures similar to those used in Experiment 1. However, it differed from Experiment 1 in the following respects. First, a slightly greater variety of decision situations were examined. Second, twice as many subjects were employed. Third, a complete within-subjects design was used.

Method

Subjects. There were 12 subjects who were paid at a fixed hourly rate for their participation in the experiment. The subjects were college students who had agreed to be part of a paid subject pool.

Stimuli. The stimuli were again information boards representing different one-bedroom apartments. The dimensions and values were basically the same as Experiment 1. The only change concerned rent, which had values of $120, $140, and $160. A decision situation involved either 2, 4, 8, or 12 alternatives, and either 4, 8, or 12 dimensions of information per alternative. Each subject received all of the 12 possible combinations of number of alternatives with number of dimensions per alternative.

Procedure. The subjects were run individually in three separate 1-hr sessions. The three sessions occurred within a 1 week interval. During each session, a subject received 4 of the 12 decision situations. The four situations received by a subject in each session involved a 2, 4, 8, and 12 alternative decision problem with some combination of the three levels of number of dimensions available per alternative. The order of presentation of decision situations was counterbalanced across sessions and subjects. The subjects were instructed to choose the apartment they would prefer.
for themselves on the basis of the information provided about each apartment. Again, if any subject specifically asked about information use they were told that they were free to look at as little or as much information as they wanted to or felt was necessary to make a decision. The same "think aloud" instructions were given to the subjects.

The subject was asked if there were any questions and then was presented with the first set of choice alternatives. The subject was allowed to rest briefly after making his or her choice and then a new set of alternatives was presented. The procedure was then repeated for a third and fourth time. The subject was then allowed to leave and reminded to come back for the second and third sessions.

The order and amount of information sought was recorded by the experimenter.

Results

Because of space limitations, the analysis of the results for this experiment will emphasize the search data. The protocols for the subjects may be obtained from the author. The search data for each subject was again primarily organized in terms of amount of available information searched and pattern of search. Table 4 presents the mean percentage of information searched across subjects for each treatment combination (number of alternatives and number of dimensions per alternative). Note that as the alternatives increased, the subjects, on the average, sought a smaller percentage of the total available information, although the total amount sought increased. Likewise, as the number of dimensions of information available increased, the total percentage of available information sought decreased. Similar results were obtained in Experiment 1.

The answer to the question of how subjects went about the process of reducing the percentage of available information sought was again provided, in part, by examining the amount of variation in information search

<table>
<thead>
<tr>
<th>Number of alternatives</th>
<th>4</th>
<th>8</th>
<th>12</th>
<th>Mean</th>
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<tr>
<td>Mean</td>
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<td>.551</td>
<td>.413</td>
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</tbody>
</table>
across the alternatives for each subject in each treatment combination. The absolute value of the difference between the percentage of information searched per alternative and the mean percentage of information searched for each treatment for each individual was calculated. A three-way analysis of variance (number of alternatives available, amount of information available per alternative, and subjects) was conducted. This test of differences among variances was proposed by Levene (cited in Keppel, 1973). The main effect of number of alternatives, $F(3, 33) = 12.36$, was significant ($p < .01$). The amount of variation in percentage of available information searched per alternative increased as the number of alternatives available increased. The main effect of amount of information per alternative, $F(2, 22) = .78$, and the interaction, $F(6, 66) = 1.10$, were not significant.

Table 5 presents a classification of the 144 search patterns exhibited by the subjects (12 subjects × 12 treatment combinations) into one of four categories depending on whether the search pattern was variable or constant in amount of information searched per alternative, and whether the pattern of search was primarily interdimensional or intradimensional. The number of instances of interdimensional, intradimensional, and shifts in information search was determined for each subject and decision situation based on the singlestep transition data. Like the results obtained from Experiment 1, in no case were there more instances of shifts in information search than instances of either interdimensional or intradimensional search. The classification of a pattern as interdimensional or intradimensional was determined by calculating the number of interdimensional singlestep transitions minus the number of intradimensional singlestep transitions divided by the sum of the two numbers. If the value of that measure was positive, the search pattern was classified as interdimensional. If the value was negative, the search pattern was classified as intradimensional. The means of this measure of interdimensional vs intradimensional search for the search patterns classified into one of the four categories are given in Table 5 as a function of number of alternatives available. The results section of Experiment 1 provides additional information on how the singlestep transition scores were determined.

The results given in Table 5 support the conclusion that as the number of available alternatives increases, subjects shift from decision strategies involving a constant amount of search per alternative, e.g., compensatory procedures, to decision strategies which involve eliminating some alternatives on the basis of only a few dimensions, e.g., conjunctive or elimination-by-aspects procedures. Additional support for the use of a strict elimination-by-aspects process by subjects was obtained by calculating the number of search patterns that showed not only a variable and intradimensional pattern but also a pattern where all (remaining) al-
alternatives would be completely searched on a dimension before some subset of those alternatives would be searched on another dimension. Thirty-three of the 108 multialternative search patterns were consistent with a strict elimination-by-aspects decision process. For 99 of the 108 multialternative choice situations (9 for each subject), the amount of available information searched was as great or greater for the alternative chosen than for any other alternative in the choice set. In the remaining nine situations, the preferred alternative had the next to the maximum amount of information searched.

Since the data for each subject in this experiment were collected in three separate experimental sessions, the question arises whether there were any obvious differences in decision procedures within subjects as a function of experimental session. An examination of the search pattern indicated little or no systematic changes in the types of search strategies observed in the first and third experimental sessions. For example, in the case of the 12 alternative choice problems, seven of the 12 subjects showed the same type of search patterns for the 12 alternative choice problems presented in the first experimental sessions as for the 12 alternative problems presented in the third and final experimental sessions. Two subjects changed from constant to variable search and three subjects changed from interdimensional to intradimensional search. On the other hand, in the case of the eight alternative choice problems, seven of the 12 subjects again showed no changes (not necessarily the same subjects as in the 12 alternative case), two subjects changed from intradimensional to interdimensional search, one subject changed from variable to constant search, and two subjects changed from interdimensional to intradimensional search.

Finally, the maximum number of dimensions searched in any decision situation was determined for each subject. The average maximum across the 12 subjects was 10.2 dimensions searched. This result is evidence

<table>
<thead>
<tr>
<th>Number of alternatives</th>
<th>Interdimensional</th>
<th>Intradimensional</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Variable</td>
</tr>
<tr>
<td>2</td>
<td>12 (.71)</td>
<td>3 (.61)</td>
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<td>12 (.73)</td>
</tr>
</tbody>
</table>
against any argument that many dimensions were completely unimportant for the subjects.

DISCUSSION

An analysis of decision maker’s information search patterns and verbal protocols has demonstrated that the information processing leading to a preferential choice will vary as a function of task complexity. The most important determinant of complexity examined was clearly the number of alternatives available. When faced with a two-alternative choice problem, subjects employed decision strategies which involved searching the same amount of information on each alternative. Such a pattern of search is consistent with the types of information processing which were shown to underlie the usual forms of two compensatory decision models. Examination of verbal protocols provided additional support for the use of either additive or additive difference types of decision processes by the subjects when faced with a two alternative choice task.

In contrast, when faced with a more complex decision task, either 6 or 12 alternatives, subjects employed decision strategies which resulted in a variable amount of information search across alternatives. A variable pattern of search had been shown to be consistent with either a conjunctive or elimination-by-aspects decision process. Both the conjunctive and elimination-by-aspects processes were proposed as ways in which people seek to reduce the amount of information processing involved in complex decision making. The protocols obtained showed that subjects tended to adopt decision strategies which would eliminate some of the available alternatives as quickly as possible and on the basis of a limited amount of information search and evaluation.

The hypothesis that increases in the complexity of a decision situation will result in decision makers resorting to choice heuristics in an effort to reduce cognitive strain was thus shown to be valid in this experiment. The use of an elimination-by-aspects choice process by a decision maker represents an example of such heuristic. More generally, the results reported in this study are consistent with a growing body of research (e.g., Mertz & Doherty, 1974; Lichtenstein & Slovic, 1973; Slovic & MacPhillamy, 1974; Payne, 1973, 1975) that argues for a contingent information processing approach to understanding decision behavior.

In that regard, the four decision processes discussed in this paper might be conceptualized as different subroutines in a general choice program. The control conditions under which one of these sets of processes might be called would then seem to depend, at least in part, on the characteristics of the decision problem. In that respect, the less cognitively demanding decision procedures, conjunctive and elimination-by-aspects, might be called early in the decision process as a way of simplifying the decision
task by quickly eliminating alternatives until only a few alternatives remained as choice possibilities. The subject might then employ one of the more cognitively demanding choice procedures, e.g., additive difference model, to make the final evaluations and choice. The protocol of Subject 2 in Experiment 1 gives clear evidence of such a combination decision processes. Other subjects also give indications of similar decision strategies. Einhorn (1971) suggested a similar explanation of decision making in complex situations.

Individual Differences

Important individual differences in information processing in decision making were shown to exist. Some of the subjects tended to search for information in an interdimensional fashion. Other subjects tended to search in an intradimensional fashion.

One possible explanation for the differences in information search may be in how the decision maker represents the knowledge he acquires about the alternatives in the decision task. For example, a decision maker might store information about the decision alternatives in the following form: Apartment A (rent, $140). This object (property, value) representation would suggest that an individual might find it easier to search and evaluate (store) information within an alternative and across dimensions. On the other hand, a decision maker might choose to code information in terms of rent (apartment A, $140). This property (object, value) representation would suggest that an intradimensional form of processing might be easier for an individual. This type of knowledge representation has been widely used in building theories of human cognitive processes (Simon & Newell, 1974). This explanation for the observed differences between subjects in information search patterns is only speculative. However, it is clear from other experiments in cognitive psychology that the way in which information is organized and filed has important consequences for our thinking (Posner, 1973). Research is needed to determine the heuristics used by individuals in setting up a format or structure for storing information about a decision problem.

Information Processing and Decision Making

The emphasis in this paper has been on examining decision behavior in terms of the information processing which led to a particular decision. This emphasis on understanding what a decision maker is actually doing can be contrasted to an emphasis on the description of his observable behavior. Description of decision behavior has been the primary focus of the years of research devoted to developing various mathematical judgment models. However, as Graesser and Anderson (1974) have recently pointed out: "To establish an algebraic model is only a first step in the analysis of the judgment process. The model is only a surface form, and
more than one underlying mechanism of integration can produce the same data pattern. On this problem, little is known, and about all that seems certain is that subjects do not consciously use a paper-and-pencil type of mental arithmetic" (p. 697). Slovic and Lichtenstein (1971) have also questioned the psychological validity of certain traditional mathematical judgment models and have argued the need to develop new models and different methods of experimentation.

The present study has demonstrated the efficacy of two process tracing techniques in identifying the information processing behavior which underlies preferential choice in a complex situation. The procedure of presenting subjects with a decision task where they would have to search for information, along with the collection of verbal protocols from subjects while actually performing the decision task, has proved valuable in illuminating the effects of two task variables on a decision maker’s processing strategies.

The next step in the analysis of decision behavior within an information processing framework would be the development of a computer program that attempts to simulate the behavior revealed in this empirical study. Efforts in that direction are currently being undertaken.

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