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Numeric and Linguistic Information Representation in Multiattribute Choice

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Numeric and Linguistic Information Representation in Multiattribute Choice

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Abstract

The form in which attribute values are represented is an important component of choice tasks. However, little evidence exists as to the impact on decision processes of representing attribute values of alternatives numerically (i.e., as numbers) versus linguistically (i.e., as words). To investigate this issue, we conducted a process tracing study of multiattribute choice in which each of 24 participants made choices among alternative computer information systems. The number and similarity of alternatives were also manipulated to examine interactions of information representation with other task and context variables. Detailed measures of decision processes were collected through concurrent verbal protocols and computer logs generated by a mouse-driven software program. Results indicate that, relative to numeric representation, linguistic attribute values lead to more alternative-based information search and less compensatory processing. Significant interactions of information representation with the number and similarity of alternatives were also found. We conclude with implications for decision research and the design of decision aids.

Numeric and Linguistic Information Representation in Multiattribute Choice

Introduction

Choosing among alternatives is one of the most pervasive, and challenging, of cognitive activities. One purpose of decision aids is to reduce the effort of choosing among alternatives. However, decision aids often intervene in the choice process by changing task features. Consequently, effectively integrating decision aids into choice tasks requires an understanding of the sometimes surprising ways in which decision makers adapt to changing task conditions (Payne, 1982).

Information in multiattribute choice tasks is often presented as the values of alternatives on the attributes that describe them. One feature of choice tasks that can be changed by decision aids is the form in which information is displayed. For example, when choosing among alternative personal computers the amount of random access memory can be represented as numbers (e.g., 640K), as words (e.g., "the most you can get on an IBM-PC"), or as pictures (e.g., a bar chart). While some aspects of information display have received considerable attention, there has been little research on the differences between numeric (numbers) and linguistic (words) information representation (Kleinmuntz & Schkade, 1989). In this study we investigate the differential effects on choice processes of representing attribute values as numbers or words.

To better understand the role of numeric and linguistic information in choice, we conducted a process tracing study in which information form was manipulated within-subjects and detailed data on decision processes and cognitive effort were collected. We also investigated the interactions of information form with two additional characteristics of choice tasks (task complexity and similarity of alternatives) that have been found to significantly affect decision processes. Cognitive cost-benefit principles are proposed as a means of understanding both the effects of information form on choice processes, and the joint effects of information form, task complexity, and similarity of alternatives. Finally, we discuss the implications of our findings for understanding decision processes and for the design of decision aids.

Information Form, Cognitive Incentives, and Strategy Selection

How might representing information as numbers or words affect decision making? Numeric and linguistic forms for attribute values are often used interchangeably in many real situations (e.g., providing consumer product information; *Consumer Reports, PC Magazine, Car and Driver*). One study has systematically investigated the effects of numeric and linguistic attribute values on decision processes. In a study of several characteristics of decision tasks, Huber (1980) presented one group of experimental participants with numeric ratings of job applicants (e.g., applicant's intelligence is a "5" on a 7 point numeric scale), and another group with linguistic ratings (e.g., applicant's intelligence is "good" on a 7 word linguistic scale). He found that in the subjects' verbal protocols, direct comparisons (e.g., computing differences or determining the maximum value of a set of numbers) were more frequent with numeric data, while evaluative statements (e.g., "that applicant has very good qualifications") were more frequent with linguistic data. One interpretation of Huber's study is that processing numeric attribute values may be less cognitively effortful under some conditions, while linguistic representations may be less effortful in others. For example, in task conditions otherwise favorable to direct comparisons using numeric information may be less effortful, while in task conditions otherwise favorable to noncomputational evaluations, using linguistic information may be less effortful.

One possible explanation for changes in decision strategies due to information form is based upon the cognitive costs and benefits of the available strategies. A frequent finding of decision research is that strategy selection is highly contingent upon characteristics of the task environment (Einhorn & Hogarth, 1981; Payne, 1982). Several authors have hypothesized that decision makers select strategies on the basis of a cognitive cost-benefit analysis (e.g., Beach & Mitchell, 1978; Johnson & Payne, 1985; Russo & Dosher, 1983; Shugan, 1980; Thorngate, 1980; Wright, 1975). Many factors could influence the costs and benefits of a strategy, but most existing research has focused on two factors: (1) the cognitive effort required to execute a strategy, and (2) the ability of a strategy to produce an accurate (i.e., correct) response (Bettman, Johnson, & Payne, in press; Johnson & Payne, 1985; Payne, Bettman, & Johnson, 1988; Russo & Dosher, 1983).

Kleinmuntz and Schkade (1989) used a cognitive cost-benefit approach to analyze the effects of information displays on decision making (Figure 1). Decision makers are assumed to choose strategies primarily on the basis of a tradeoff between the anticipated cognitive effort and the anticipated accuracy of various strategies. Four classes of factors are hypothesized to influence anticipated effort and accuracy, and therefore to define a *cognitive incentive system* for strategy selection. The *information display* includes the form and features of individual attribute values, how the alternatives and attribute values are configured on a display, and whether the display remains static or changes over time. *Task characteristics* are structural characteristics of the decision problem, including the number of alternatives, the number of attributes, time pressure, etc. *Context characteristics* are features of the particular attribute values of the alternatives under consideration, including redundancy of the attributes, the presence or absence of dominated alternatives, and the similarity of attribute values for different alternatives (see Payne, 1982, for a discussion of the distinction between task and context characteristics). *Decision maker knowledge* includes "metaknowledge" about the available strategies and their characteristics, the relationship between strategies and the task setting, and specialized knowledge about the problem domain. Decision makers are assumed to choose decision strategies based upon the anticipated effort and accuracy resulting from the interrelationships of these four factors.

Insert Figure 1 about here

Representing information in different forms (one aspect of information display) may affect the effort of particular cognitive operations that are components of strategies. For example, computing differences within attributes is probably less effortful with numeric attribute values (e.g., "640K of memory is 128K more than 512K") than with linguistic representation (e.g., how much more is an "excellent" memory capacity than a "good" one?). The low cognitive effort of comparisons associated with numeric information should also be associated with greater use of attribute-based processing (i.e., processing within attributes), since attribute-based processing is logically related to the use of comparison operations (Russo & Dosher, 1983). Johnson, Payne, and Bettman (1988) make a similar interpretation of their finding that subjects used less computationally-intensive strategies when probabilities were presented as complex fractions rather than as equivalent, but simple, decimals (i.e., since calculations are easier with simple decimals).

However, Figure 1 suggests that the anticipated costs and benefits of decision strategies include consideration of not only the information display, but also task, context, and decision maker knowledge. We therefore also consider the effects of one task characteristic (complexity) and one context characteristic (similarity of alternatives) that have been found to be influential in strategy selection (Payne, 1982).

Task complexity has been found to have important effects on strategy selection, and to have interactive effects with other characteristics of the decision environment (Ford, Schmitt, Schechtman, Hults, & Doherty, 1989; Payne, 1982). Task complexity has generally been operationalized as: (1) the number of alternatives in a choice set, (2) the number of attributes comprising each alternative, or (3) the time available for decision making. We focus on the number of alternatives, since varying the number of alternatives appears to affect decision processes more significantly and consistently than other definitions of task complexity (Payne, 1982). Previous research also suggests that as the number of alternatives increases, so does the use of attribute-based processing (Payne, 1976; Payne & Braunstein, 1978). Such contingent decision behavior is consistent with a cost-benefit explanation, since, if attributes are not scaled on a common metric, combining information across attributes is more effortful than within an attribute (Tversky, 1969). Thus, as task complexity increases, decision makers shift strategies to manage the increased cognitive load.

Similarity of alternatives has also been found to be an important factor in decision strategy selection (Biggs, Bedard, Gaber, & Linsmeier, 1985; Russo & Dosher, 1983; Russo & Rosen, 1975; Rosen & Rosenkoetter, 1976; Tversky, 1977). Payne (1982, p. 393) emphasizes the importance of similarity: "... any theory of decision making that allows for contingent processing will have to incorporate similarity structure among alternatives as an essential component of the theory." We define similarity as the extent to which attribute levels of different alternatives are close together (cf. Russo & Rosen, 1975). For example, two Toyota subcompact sedans have similar values for interior room, miles per gallon, ease of service, etc.. A Ford van and a Toyota subcompact sedan have very different attribute levels, and are therefore distinctive.

Two divergent perspectives exist on the effects of similarity on decision making. Russo and Rosen (1975, pg. 267) assert that "...similarity facilitates choice," and find that choice accuracy increases with similarity. One explanation for the higher accuracy of choices between similar alternative is that small differences between alternatives may be estimated more accurately than large differences (Russo & Dosher, 1983). In contrast, Tversky (1977, pg. 335) states that, in judgments of similarity: "The more similar the stimuli, the more likely they are to be confused." One implication of this argument is that choice between similar stimuli may be more effortful than between distinctive stimuli.

To summarize, we hypothesize that decision makers will use different strategies when the attribute values of choice alternatives are represented as words rather than as numbers. Specifically, changing the form in which attribute values are represented may change the ease with which various cognitive operations can be executed. Decision makers should adapt to this change in cognitive incentives by choosing strategies whose component operations are easy to execute with the given attribute representation. The primary objective of the experiment is to explore this hypothesis. Because there is little empirical evidence of the effects of information form on decision processes, we also manipulate task complexity and similarity of alternatives to look for possible boundary conditions on any effects of information form.

Method

Task. Participants were instructed to choose the "best" computer-based information system from a set of alternatives characterized on four attributes. Alternatives were displayed on one dimension of a matrix, and attributes on the other (Figure 2). Such displays are recommended in the information systems literature as an "... effective means of presenting and comparing the basic functions of each candidate [information system]" (Gore & Stubbe, 1983, p. 245; also see Burch & Grudnitski, 1986, p. 501). The four attributes presented in all choices were "cost economy," "documentation," "ease of use," and "expandability."[1] Experimental materials were pretested to establish that they were understandable and realistic.

Insert Figure 2 about here

Procedure. Twenty-four graduate business students with an average of 5.1 years of work experience and at least one graduate course in data processing participated for course credit. Each participant completed two separate individual sessions of about one hour. In one of the sessions, they were presented with numeric attribute values, and in the other, linguistic. The two sessions were scheduled at least six days apart to reduce carry-over effects. The procedures for the two experimental sessions were identical, except that participants answered demographic and debriefing questions following the second session.

Design. The principal independent variable was information form. In addition, the number of alternatives, and the similarity of alternatives were manipulated. All independent variable manipulations were within-participant. There were two information forms (numeric, linguistic), three levels of complexity (two, four, and eight alternatives), and two levels of the similarity of alternatives (distinctive, similar). Participants made two choices in each of the 12 treatment combinations, for a total of 24 choices for each participant. Participants also made five practice choices in each session to familiarize them with the task and the software used in the experiment. On average, participants required about 100 seconds per choice problem.

There was a direct correspondence between the numeric and linguistic forms of the problem. For example, a "2" in the numeric condition, corresponded to a "very poor" in the linguistic condition (Table 1). Participants were informed of the correspondence of the numeric and linguistic forms in initial task instructions.[2] The linguistic scale used in the experiment was constructed based upon previous research in psychological scaling (Myers & Warner, 1968). Adjectives for scale labels were chosen to be easily understood and approximately equidistant.[3]

Insert Table 1 about here

Similarity was operationalized as the variability of alternatives in a choice set. High variance alternatives contain more extreme attribute ratings (e.g., System 2A in Table 2), while low variance alternatives contain more moderate attribute ratings (e.g., System 1A in Table 2). To illustrate this operationalization, let V_i be the variance of the levels of the four attributes for alternative i (i.e., V_{1A} = var(6, 6, 6, 6) = 0, V_{2A} = var(10, 2, 2, 10) = 16). The variability of the choice set is the variance, across alternatives, of the V_is in the choice set. For example, the variance of choice set A is var(0, 16) = 64. Distinctive (i.e., high variability) choice sets contained alternatives with substantially different variances (e.g., Choice Set A). Similar (i.e., low variability) choice sets contained alternatives with similar variances (e.g., Choice Set B).

Insert Table 2 about here

As Table 2 illustrates, the sum of the ratings for all alternatives always equaled twenty-four. The sum of the ratings for alternatives was held constant for two reasons. First, to make the choice problems more difficult, increasing the likelihood of observing effects due to cognitive effort. And second, to separate effects due to choice set similarity from those related to the individual attractiveness of alternatives, or the presence or absence of dominated alternatives.

Several factors were counterbalanced: whether numeric or linguistic information was presented in the first session, whether alternatives appeared as rows or columns, the order in which the alternatives and attributes were displayed, and whether the complexity manipulation came in increasing (2-4-8) or decreasing order (8-4-2). All counterbalancing was between-participants. A fractional factorial design was used to select combinations for counterbalanced factors (Hays, 1981).

Data Collection. The choices were displayed using an IBM PC-AT microcomputer equipped with a mouse, and *Mouselab*, a software system designed to record traces of decision processes (Johnson, Payne, Schkade, & Bettman, 1988). Using *Mouselab*, when a choice set first appears on the screen, the information about the alternatives is "hidden" in labeled boxes (Figure 2). These boxes can be "opened" to reveal their contents by using the mouse to move the cursor into a given box. Only one box can be open at a time. Participants make choices by moving the cursor to the choice box of the desired alternative, and clicking a mouse button. Figure 3 illustrates an experimental display after a cell has been "opened."

Insert Figure 3 about here

Two types of data were collected: (1) computer logs and, (2) concurrent verbal protocols. *Mouselab* records the sequence of cells opened, the time spent in each cell, and the choice made by a participant. Protocols were collected for the last six choices in each of the two experimental sessions. Participants received instructions on generating protocols and completed two practice protocol trials after the first six choices and before the last six choices. Evidence suggests that verbal protocols are less intrusive after participants have made decisions without protocols (Russo, Johnson, & Stephens, 1986).

The taped verbal protocols were transcribed and segmented into a series of complete thoughts (Newell & Simon, 1972). The first author and a paid rater who was unaware of the purpose of the experiment then independently coded the protocols into one of ten categories constructed to provide relatively complete coverage of expected decision operations used in choice tasks, and to capture expected differences in strategies due to information form (Table 3).[4] The two raters agreed initially on 79% of codings. The Kappa Coefficient (Bishop, Fienberg & Holland, 1975), which measures the proportion of agreement between coders, less the agreement that can be attributed to chance, was 71%, with a 95% confidence interval ranging between 69% and 73%. The remaining differences were resolved through discussion.

Insert Table 3 about here

Dependent Variables. Two approaches were used to analyze the large set of possible decision strategies used by decision makers. First, broad measures of strategy characteristics were computed, rather than attempting to characterize the strategy used on each trial as an integrated whole. Second, strategies were decomposed into sequences of elementary processing operations, such as reading a piece of information, or multiplying a probability and a payoff (Bettman et al., in press; Chase, 1978).

Two broad measures of decision strategies are the information search pattern and measures of overall effort (Payne, Braunstein, & Carroll, 1978). Information search patterns concern the sequences in which the attribute values for various alternatives are read and processed. One dimension of information search processes is the direction of search, which can be organized around either alternatives or attributes (Payne, 1976). Attribute-based search consists of acquiring information primarily one attribute at a time (e.g., examine "cost" information for each of a set of microcomputers, then "random-access memory", and so on), while alternative-based search consists of acquiring information primarily one alternative at a time (e.g., look at all attributes of one microcomputer, then go to the next, etc.).

To characterize information search, a direction of search index (Payne, 1976) was computed. This index measures the extent of attribute-based and alternative-based processing. If the nth + 1 piece of information searched is within the same attribute as the nth (i.e., an intra-attribute transition), the statistic moves towards +1. If the nth + 1 piece of information searched is within the same alternative (i.e., an intra-alternative transition), the statistic moves towards -1.

$$D = \frac{(Inter - Intra)}{(Inter + Intra)} \qquad (1)$$

where: Inter = the number of inter-attribute transitions
Intra = the number of intra-attribute transitions

Three measures of decision effort were used: (1) total time to make a decision, (2) total transitions, and (3) total number of elementary processing operations. Total transitions indicate the number of attribute values examined, including reexaminations of previously acquired values. An explanation of the analysis of elementary processing operations follows.

In addition to characterizing strategies using broad, overall measures, strategies (as evidenced by concurrent verbal protocols) were decomposed into elementary processing operations. Research suggests that the decomposition of strategies into elementary operations can produce veracious descriptions of choice behavior and that, "... a small number of simple operators can be viewed as the fundamental underlying components from which subjects construct decision rules" (Bettman et al., in press; see also Chase, 1978). For each choice episode, the categories (see Table 3) and total number of elementary operations used by a participant were analyzed.

Multivariate analysis of variance (MANOVA) was used to evaluate the data. Separate analyses were run for variables derived from protocol data and from computer logs.[5] Verbal protocol operations were stated as proportions of total operations used (e.g., read operations/total operations) and were analyzed using a variance-stabilizing arcsin transformation (Neter & Wasserman, 1974).

Results

Results are presented in five subsections, organized around dependent variables: (1) information search, (2) cognitive effort, (3) linkages between information search and cognitive effort, (4) variety of decision strategies, and (5) choice. Overall MANOVA results show significant main effects in the computer log data for information form (Wilks' Lambda = .970, F(3,539) = 5.83, p = < .001), task complexity (Wilks' Lambda = .553, F(6,1078) = 62.0, p = < .001), and the variability of alternatives (Wilks' Lambda = .927, F(3,539) = 14.12, p = < .001). Overall MANOVA main effects for the verbal protocol data are also significant for all three independent variables (information form (Wilks' Lambda = .588, F(10,232) = 16.26, p = < .001), task complexity (Wilks' Lambda = .402, F(20,464) = 13.41, p = < .001), variability of alternatives (Wilks' Lambda = .871, F(10,232) = 3.44, p = < .001)). Additional analysis was conducted to explain these effects.

Information Search. There are significant main effects of information form, task complexity, and similarity on the direction of search index (Table 4). Across all experimental conditions, the direction of search was predominantly alternative-based (i.e., direction of search index > 0). The direction of search index was significantly more alternative-based with linguistic information, with less complex problems (i.e., 2 and 4 alternatives), and with distinctive alternatives.

Insert Table 4 about here

The protocol data provide insight into the adaptations of information search to information form (Table 5). With numbers, participants used more *compare* operations, perhaps indicating a tendency to acquire attribute values in pairs. Attribute-based processing is heavily dependent upon comparisons within attributes to isolate significant differences between alternatives (Russo & Dosher, 1983). In contrast, with words participants used fewer *compare* but more *read* operations, presumedly to acquire values one at a time.

Insert Table 5 about here

Protocol data also provide insight into the adaptations of information search to task complexity. As the number of alternatives increased, participants used the *read*, $F(2,241) = 4.72$, $p = .009$, and *elimination*, $F(2,241) = 38.26$, $p < .001$, operations more frequently. The greater frequency of *read* operations may indicate an increase in scanning for unusual characteristics that might provide the basis for simplification. Similarly, the increase in *elimination* operations suggests that as the task became more difficult, participants simplified the problem by more frequently eliminating alternatives, and switching to attribute-based search (cf. elimination-by-aspects; Tversky, 1972).

As task complexity increased, the direction of search index shifted more quickly toward attribute-based processing with numeric attribute values than with linguistic, $F(2,541) = 3.5$, $p = .032$ (Figure 4). In the linguistic condition, this shift still occurred but is much less pronounced. Apparently, increased use of attribute-based search was used by participants to adapt to the increasing cognitive load caused by a larger number of alternatives. The more significant movement towards attribute-based processing in the numeric condition, relative to the linguistic, suggests that decision makers were better able to adapt search processes to task demands with a numeric representation.

Insert Figure 4 about here

<u>Cognitive Effort</u>. The means for all measures of cognitive effort were greater with the linguistic representation, although the differences were only marginally significant (total cognitive operations, $F(1,241) = 3.8$, $p = .054$; total time, $F(1,541) = 1.4$, $p = .238$; total transitions, $F(1,541) = 2.4$, $p = .125$). Our results therefore offer weak evidence of slightly greater decision effort with a linguistic relative to a numeric representation.

Despite the absence of substantial main effects due to information form in measures of effort, the protocols suggest greater use of noncompensatory processing strategies with the linguistic representation (see Table 5). In the numeric condition, participants made more frequent use of the *attribute importance*, *tradeoff*, *evaluate*, *external standard*, and *summarize* operations. In contrast, in the linguistic condition participants made more use of *read* and *elimination* operations. These results are consistent with greater use of compensatory processing in the numeric condition (e.g., considering attribute importance and making tradeoffs).

Choosing among similar alternatives was more effortful than among distinctive alternatives on all measures of cognitive effort (total operations, $F(1,241) = 19.0$, $p < .001$; total time, $F(1,541) = 29.6$, $p < .001$; total transitions, $F(1,541) = 38.2$, $p < .001$).[6] This result is consistent with prior findings that choice between similar alternatives is more effortful than between distinctive alternatives (e.g., Biggs et al., 1985; Tversky, 1977).

As the similarity of alternatives increased, participants used the *attribute importance* operation more frequently ($F(1,241) = 6.65$, $p = .010$), but made less use of the *summarize* operation ($F(1,241) = 12.53$, $p < .001$). Since similar alternatives also resulted in decreased use of alternative-based search (Table 4), one possibility is that some participants identified differences between alternatives on attributes (e.g., the additive-difference strategy) as a means for distinguishing between similar alternatives.

One implication of such a strategy is that choosing between similar alternatives with linguistic information is highly effortful. The effort of choice between similar alternatives is reduced by greater use of attribute-based processing and consequently, comparisons within attributes. However, the linguistic representation increases the cognitive effort of comparisons and attribute-based processing. This interpretation is evident in a significant interaction of information form and similarity on effort (Figure 5). With distinctive choice sets, the numeric representation was slightly more effortful, but with similar choice sets, the linguistic representation was much more effortful. This effect is significant for both total time (Figure 5 - Panel A) ($F(1,541) = 3.95$, $p = .047$) and total transitions (Figure 5 - Panel B) ($F(1,541) = 5.96$, $p = .015$).

Insert Figure 5 about here

Information Search and Cognitive Effort. It has often been suggested that attribute-based processing is easier than alternative-based processing, since different attributes are generally expressed in different units or on different scales (e.g., Payne, 1976; Tversky, 1969). However, we find a significant *negative* correlation between the search index and total time, $r = -.19$, $p < .01$, and total transitions, $r = -.15$, $p < .01$, meaning that on average, alternative-based search was less effortful. Analysis of covariance confirms that this negative relationship remains even after controlling for the effects of the manipulated variables (total time, $F(1,540) = 4.69$, $p = .030$; total transitions, $F(1,540) = 3.04$, $p = .082$). This effect is concentrated in the linguistic condition, especially in the cells with similar alternatives (Table 6). In the numeric condition there is essentially no effect, while in the linguistic condition, five of the six correlations are negative, and those in the cells with similar alternatives are the largest and most negative. Thus, our results suggest that attribute-based search is not invariably less effortful. Rather, the relative effort of information search strategies is dependent upon the interrelationships of task, context, and information display.

Insert Table 6 about here

Variety of Decision Strategies. In conditions where the cognitive incentives are favorable, we might expect decision makers to use a greater variety of processing operations. If a greater diversity of operations is used, then the frequency distribution of operator use should be dispersed, resulting in a larger variance. For example, in Table 5 the measure would be relatively lower for the linguistic condition since the majority of frequencies are concentrated on one operation (the read operation), but higher in the numeric condition where frequencies are more evenly distributed. ANOVA confirms that participants employed a larger variety of operations in the numeric condition, $F(1,241) = 19.0$, $p < .001$.

Choice. There were no systematic differences in choices between the numeric and linguistic conditions.[7] These (non)results can be interpreted as a check on the validity of the information form manipulation. If differences in choice were found, one interpretation would be that the linguistic and numeric information forms presented to participants were perceived as substantively nonequivalent. Alternatively, there is evidence that information form can influence the weight attributed to information cues (Bell, 1984). While the focus of this study was on decision processes, future research should investigate conditions under which information form can affect decision outcomes.

Discussion and Implications

Our results show that numeric and linguistic representations of attribute values can lead to quite different choice processes. With numeric attribute values participants used relatively more attribute-based search, and made more frequent use of several cognitive operations, including comparisons, evaluations, summarizations, references to external standards, statements of attribute importance, and tradeoffs. In contrast, with linguistic attribute values participants used relatively more alternative-based search, and more frequent use of several different operations, including reading of individual values, and explicit elimination of alternatives. We also found weak evidence that processing linguistic information may require slightly more cognitive effort than numeric information. Where comparable, our results are generally consistent with those of Huber (1980), with the few differences apparently resulting from differing verbal protocol coding categories.[8]

We have also seen that task complexity and similarity of alternatives may have important moderating influences on the effects of information form. As task complexity increased, participants processing numeric information significantly increased use of attribute-based search. In contrast, participants processing linguistic information maintained relatively constant information search processes as task complexity increased. One interpretation of this result is that numeric information permits greater adaptation of information search strategies to task demands.

Information form and similarity of alternatives appear to have joint effects on cognitive effort. As similarity increased, thereby increasing cognitive effort, participants processing numeric information exhibited modest increases in cognitive effort. In contrast, participants processing linguistic information evidenced much greater increases in cognitive effort. This result implies that numeric attribute values permit decision makers to better manage cognitive effort across changes in task difficulty.

Our results raise two intriguing issues for decision research. First is the possible existence of limits to the adaptiveness of decision behavior. Decision makers adapted more readily to changing task conditions with a numeric attribute representation than with a linguistic representation. Recent research investigating time pressure in decision performance suggests that decision strategies vary in their ability to adapt to time constraints (Payne et al., 1988). Our results indicate that information form is another factor that may constrain the available decision strategies, thereby limiting the capacity to adapt to environmental conditions. Consequently, the empirical f[illegible]gs of choice research obtained with numeric attribute representations [illegible] generalize to those with linguistic representations.

Second is the large impact of th[illegible]arity of alternatives on choice. Increasing choice set similarity resulted in less alternative-based search, greater consideration of attribute importance, fewer summaries of alternatives, and most importantly, greatly increased cognitive effort. Our results, therefore, contrast with Russo & Rosen (1975, pg. 267), who observe that in choices between two alternatives, "...similarity facilitates choice." All measures of decision effort increased with similar choice sets, even in choices between two alternatives. Our results are consistent with Tversky (1977) and Biggs et al. (1985), who argue that the more similar the stimuli, the more difficult the choice.

Decision Processes and Adaptation. One aspect of our results is seemingly paradoxical. Participants adapted to increasing task complexity by greater use of attribute-based search (Figure 4). Overall however, using attribute-based search increased effort (Table 6). Did the use of attribute-based search increase or decrease cognitive effort?

Previous research suggests that alternative-based processing is more effortful (Russo & Dosher, 1983). However, with uniformly scaled attributes, the effort of alternative-based processing is reduced. In both the numeric and linguistic conditions all attributes were scaled identically, using the same five numbers (i.e., "2", "4" , etc.) or the same five words (i.e., "very poor", "poor", etc.). As a result, the effort of inter-attribute comparisons was minimized, thereby decreasing the effort of alternative-based processing. Uniformly scaled attributes apparently made alternative-based processing less cognitively effortful than attribute-based processing, especially with linguistic attribute values.

A second unexpected result may also be due to the uniform scaling of attributes in our task. The overall extent of alternative-based processing in our data is greater than that previously observed in riskless, multiattribute choice tasks (e.g., Bettman & Jacoby, 1976; Olshavsky, 1979; Payne, 1976). Prior research has found a predominance of attribute-based processing (Bettman, 1979; Russo & Dosher, 1983), except in choice tasks with logically interdependent attributes, such as gambles (Johnson, Payne, & Bettman, 1988; Payne & Braunstein, 1978). The reduced effort of alternative-based information search with uniform scaling provides one explanation for this result. Since there is evidence that alternative-based processing improves decision accuracy (Russo & Dosher, 1983), future research should investigate whether choice accuracy can be improved and cognitive effort reduced by using uniform attribute scaling.

Compatibility of Task, Context, and Information Form. Recent research suggests that an important component of the usefulness of information is the compatibility of information form with decision task and context (Jarvenpaa, 1989; Slovic, Griffin, & Tversky, in press; Tversky, Sattath, & Slovic, 1988; Vessey, 1988). Our results support this conceptualization. When participants chose between similar alternatives using linguistic information, all measures of decision effort increased significantly. This increase in effort can be explained by considering the processing operations used to adapt to linguistic information and similar alternatives. When presented with linguistic information, participants used more alternative-based search, considered attribute importance less frequently, and made fewer comparisons. When choosing between similar alternatives, participants used more attribute-based processing, considered attribute importance more frequently, and made (marginally) more comparisons.

When choosing between similar alternatives with linguistic information however, participants faced the bewildering prospect of a context (i.e., similar alternatives) that favored attribute-based information search, more comparisons, and greater consideration of attribute importance, combined with an information form (i.e., linguistic) that favored alternative-based search, fewer comparisons, and less consideration of attribute importance. We argue that the incongruity between information form and context produced the significant increases in cognitive effort evident in participants' choices between similar alternatives with linguistic attribute values.

Tversky, Sattath, and Slovic (1988) demonstrate the importance of compatibility between the information form of cues and response modes. In their research participants changed the weighting given to information cues as the compatibility between the information form of the cues and the response mode changed. For example, participants gave greater weight to ordinal or qualitative cues when choosing between alternatives and greater weight to quantitative cues when rating or pricing alternatives. Future research should relate these results to linguistic and numeric information forms. For example, when decision makers use both linguistic and numeric attributes in choice, do linguistic attributes receive greater weight than numeric attributes, since choice tasks require a qualitative response?

Decision Making and Language. Wallsten and colleagues (e.g. Erev & Cohen, in press; Wallsten, in press; Wallsten, Budescu & Erev, in press) have also observed cognitively-based differences in perceptions of numeric and linguistic information. This research suggests that linguistically expressed uncertainty (e.g., a "good" chance of rain) may be translated into an implied probability interval (e.g., 50-70% chance of rain) to resolve the vagueness of linguistic expression (Wallsten, Budescu, Rapoport, Zwick & Forsyth, 1986). Probabilities that are themselves uncertain (e.g., a 50-70% chance of rain) may be more accurately communicated using a linguistic representation, since linguistic expression may suggest information about both the probability itself, and the relative certainty of the estimate (Wallsten, in press; see also Daft & Wiginton, 1979). Probabilities with no underlying uncertainty (e.g., the likelihood of drawing a king from a deck of cards) may be more accurately communicated using a numeric representation.

Wallsten and colleagues' theory suggests a possible explanation for the reduced adaptive capacity exhibited by decision makers in the linguistic condition. The linguistic representation in our experiment may have implied that the attribute values were only "estimates." Participants may therefore have considered not only the raw linguistic value, but also the implied uncertainty of these estimates. If uncertain data is in fact more informatively expressed in linguistic form, it may also be the case that the cost of this "richer" information is reduced adaptive capacity.

Decision Aiding. This research also provides evidence relevant to the development of a theoretical framework for designing computer-based decision aids. Decision makers change strategies in response to changes in information displays, task conditions, and decision context (Kleinmuntz & Schkade, 1989; Payne, 1982). Our results demonstrate that changing the form in which information is presented may alter the cognitive incentives of alternative decision strategies. However, information form interacts with other task and context characteristics, suggesting that the relationship between information displays and decision processes cannot be considered in isolation from other factors.

The engineering of computer-based information displays to meet the processing and/or performance goals of decision makers has the potential to significantly improve decision making (Kleinmuntz & Schkade, 1989; Todd and Benbasat, 1988). Improved decision making however, is contingent upon an improved understanding of the complex relationships between information displays, task characteristics, decision context, and expertise. By coupling our improving knowledge of decision processes with advances in computing technology, decision researchers and designers of decision aids have the potential to not only understand why choice between alternatives is frequently challenging, but to make it significantly less so.

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Author Notes

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Notes

[1] These four attributes were chosen based upon a review of factors commonly identified as important in choosing IS (Burch & Grudnitski, 1986; Gore & Stubbe, 1983; Wetherbe 1984).

[2] These instructions made it theoretically possible for participants to convert linguistic information to numeric form, and vice versa. An analysis of verbal protocols revealed some participants converting linguistic information to numeric form on early pretrial choices, but quickly abandoning this strategy, presumedly due to the cognitive effort required to maintain such conversions.

[3] To test the equivalence of the numeric and linguistic scales, 83 participants were asked to provide equivalent numeric values, between and including 2 and 10, for the linguistic labels in Table 2. Means and standard deviations for linguistic labels were:

	very poor	poor	fair	good	excellent
Mean:	2.08	3.87	5.82	7.85	9.88
Std. Dev.	(.4094)	(.4814)	(.4911)	(.4190)	(.3381)

[4] Verbal protocol categories were adapted from Johnson & Payne (1985).

[5] Recall that verbal protocols were obtained for only the last 6 choices in each experimental session.

[6] Examination of the protocols for explicit statements of problem difficulty (e.g., "This one is hard...", "Because there are so many here ...") reveals a significant difference due to the similarity of alternatives ($F(1,241) = 15.29$, $p < .001$), with more statements of problem difficulty occurring with similar alternatives.

[7] Chosen alternatives were analyzed using measures of the relative consensus of participants, the variance of the chosen alternative, the maximum values contained in

chosen alternatives, and the minimum values contained in chosen alternatives. None were significant at the .10 level.

[8] Huber found more comparison operations with numeric data and more evaluation operations with linguistic data. In contrast, we find more comparisons and evaluations with numeric data, and more individual acquisitions of information and eliminations of alternatives with linguistic data. However, Huber did not include read and elimination operations as categories. Statements coded as evaluations in Huber's study are therefore likely coded as reads and eliminations in our research.

Table 1

Correspondence Between Numeric and Linguistic Data

Numeric Data :	*2*	*4*	*6*	*8*	*10*
Linguistic Data :	*very poor*	*poor*	*fair*	*good*	*excellent*

Table 2

Similar and Distinctive Choice Sets (with Additional Statistical Information)

Choice Set A - Distinctive Alternatives

	System 1A	System 2A
Ease of use	6	10
Cost economy	6	2
Expandability	6	2
Documentation	6	10
Choose one:	System 1	System 2
Statistics for the choice set:		
Sum of the ratings of the alternative	(6+6+6+6) = 24	(10+2+2+10) = 24
Variance of the alternative	= 0	= 16

Variance of the choice set = var(0,16) = 64

Choice Set B - Similar Alternatives

	System 1B	System 2B
Ease of use	6	2
Cost economy	10	6
Expandability	4	8
Documentation	4	8
Choose one:	System 1	System 2
Statistics for the choice set:		
Sum of the ratings of the alternative	(6+10+4+4) = 24	(2+6+8+8) = 24
Variance of the alternative	= 6	= 6

Variance of the choice set = var(6,6) = 0

Table 3

Elementary Information Processing Operations
(Adapted from Johnson & Payne, 1985)

ATTRIBUTE IMPORTANCE	State importance of an attribute.
CHOOSE	Announced preferred alternative and stop process.
COMPARE	Compare two alternatives on an attribute.
ELIMINATE	Remove an alternative from consideration.
EVALUATE	Evaluate problem information (with no reference to an external standard).
EXTERNAL STANDARD	Refer to a standard or criterion for an acceptable alternative or attribute value.
READ	Read value for an alternative on a particular attribute.
SUMMARIZE	Summarize an alternative.
TRADE OFF	State trade off between attributes.
OTHER	Other statement or operation.

Table 4

Mean Direction of Search Indices by Experimental Condition

	Mean	Std. Dev.	F Value	p
Information Form				
Numeric	.320	.416	14.21*	.001
Linguistic	.410	.382		
Similarity of Alternatives				
Distinctive	.391	.421	5.63*	.018
Similar	.336	.380		
Task Complexity				
2 alternatives	.511	.362	49.33**	.001
4 alternatives	.346	.379		
8 alternatives	.232	.414		

* F(1, 541)

** F(2, 541)

Table 5

Percentage of Processing Operations in Numeric and Linguistic Conditions

	Numeric	Linguistic	F value *	p
READ	.258	.528	155.57	< .001
COMPARE	.143	.065	30.95	< .001
ELIMINATE	.052	.068	2.83	.093
EVALUATE	.157	.076	29.94	< .001
ATTRIBUTE IMPORTANCE	.046	.029	6.63	.010
TRADE OFF	.015	.010	5.61	.018
SUMMARIZE	.092	.060	3.80	.052
CHOOSE	.087	.075	1.48	.224
EXTERNAL STANDARD	.049	.024	12.61	< .001
OTHER	.101	.065	7.71	.005
TOTAL	1.00	1.00		

Note: Tests of significance were performed on arcsin transformed proportions (Neter and Wasserman 1974).

* (1, 241)

Table 6

Correlations Between the Direction of Search Index and Total Transitions

	Number of Alternatives		
	Two	Four	Eight
Numeric			
Similar	-.13	.12	.10
Distinctive	.00	.00	.18
Linguistic			
Similar	-.18	-.23	-.32
Distinctive	-.07	-.16	.02

Figure 1

(Adapted from Kleinmuntz and Schkade, 1989)

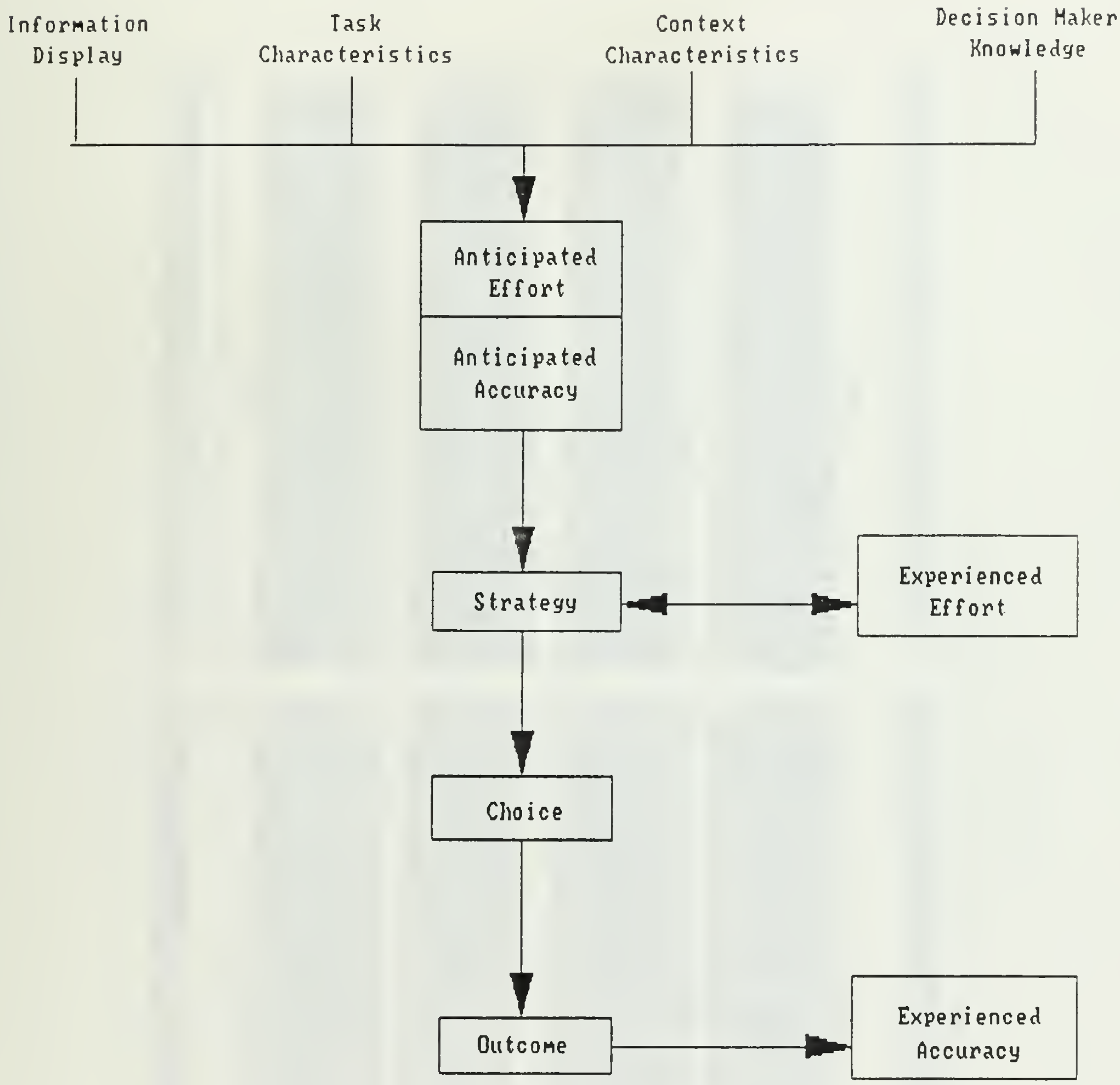


Figure 2

Initial Presentation of a Choice Set

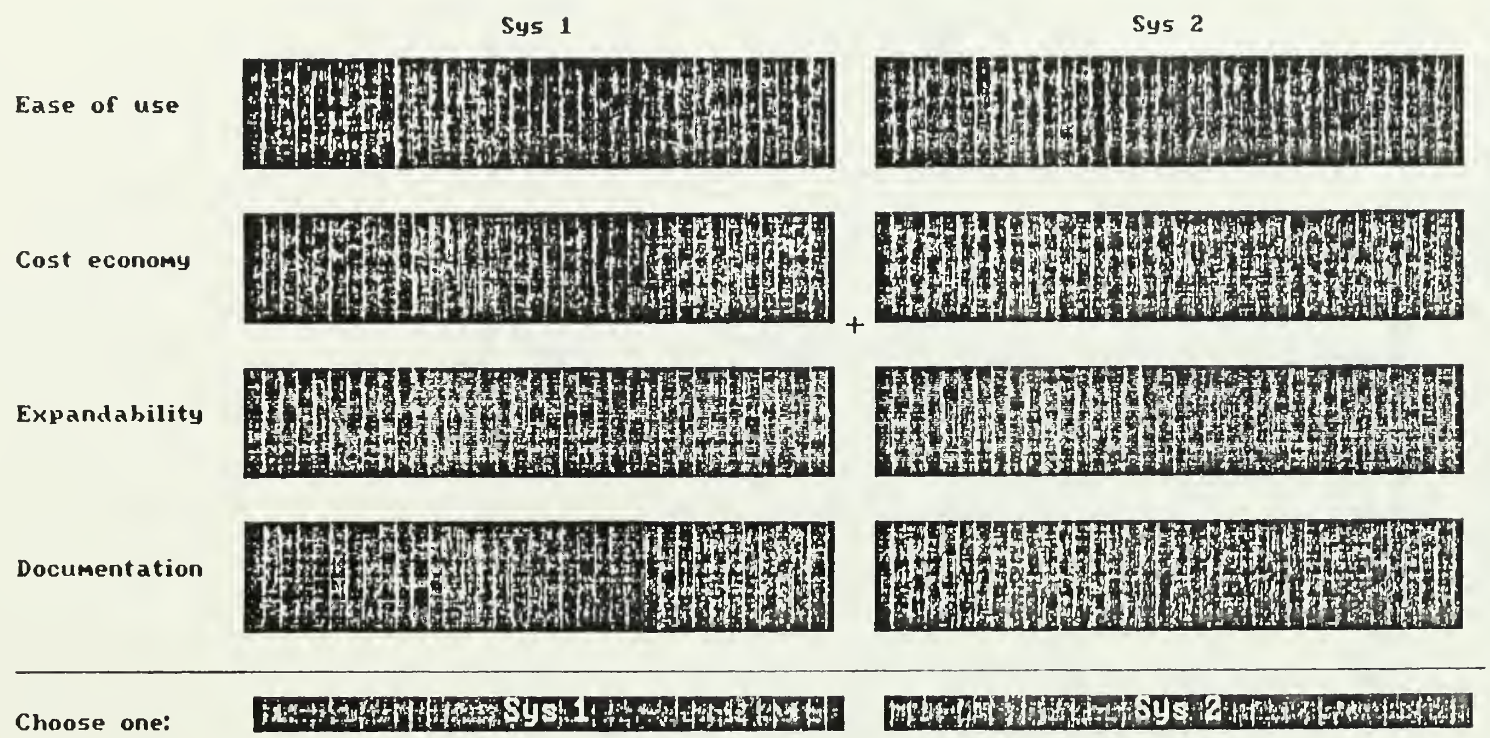


Figure 3

Choice Set With "Opened" Box

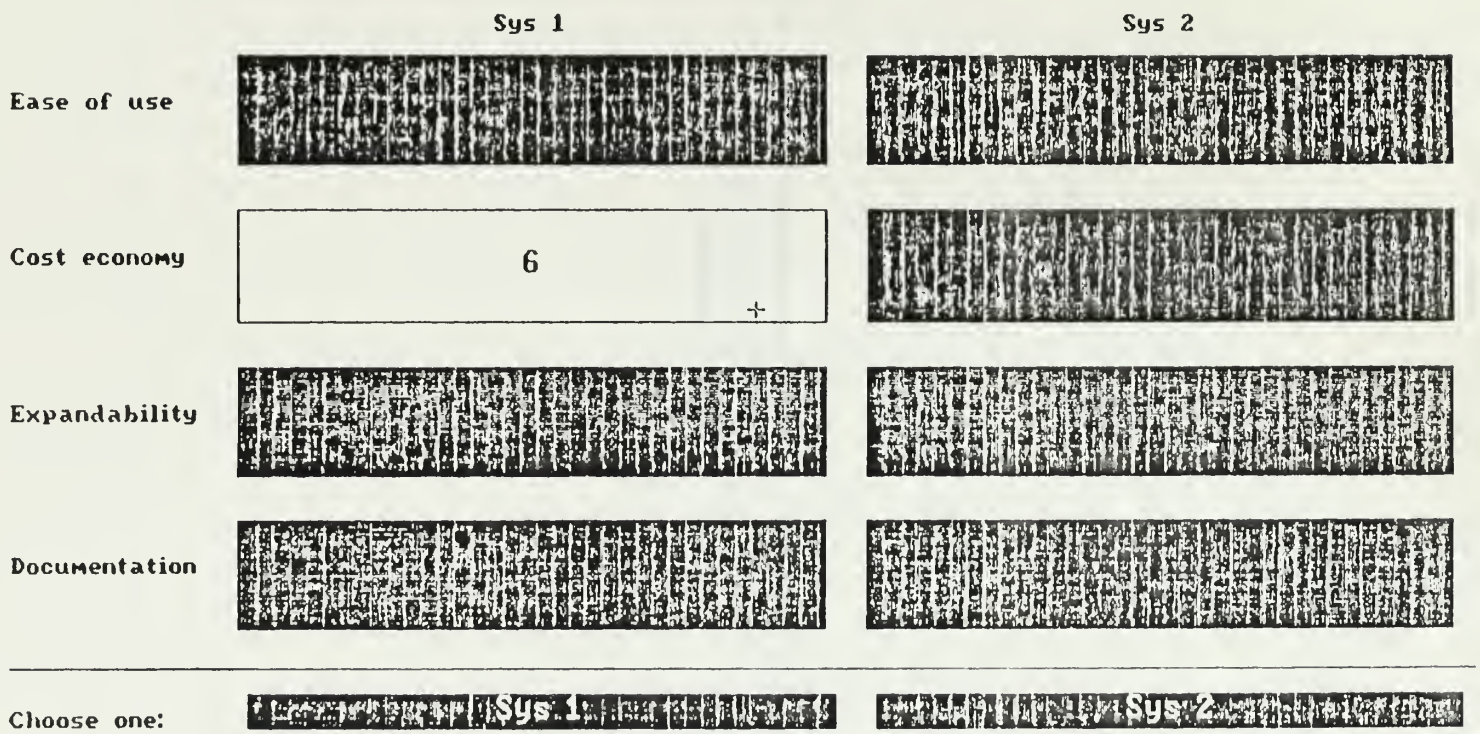


Figure 4

Direction of Search by Information Form and Task Complexity

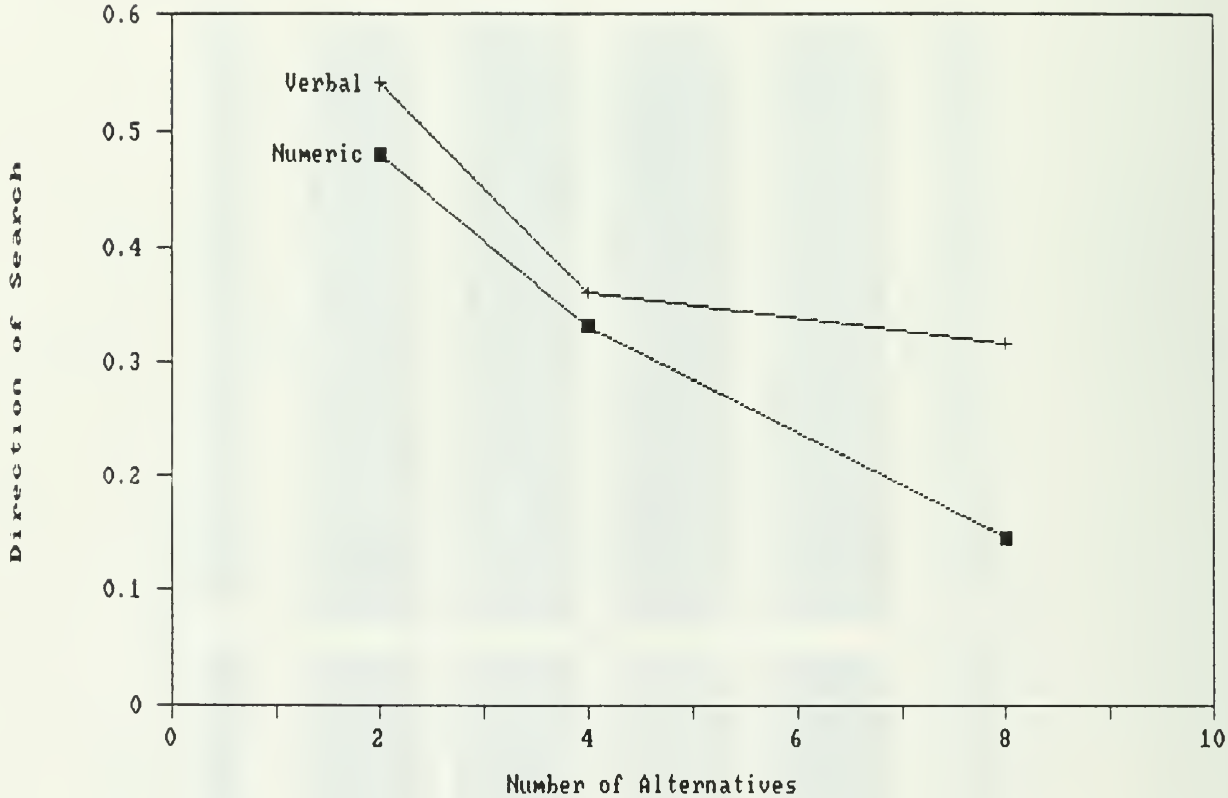


Figure 5 - Panel A

Total Time to make a Decision by Information Form and Similarity of Alternatives

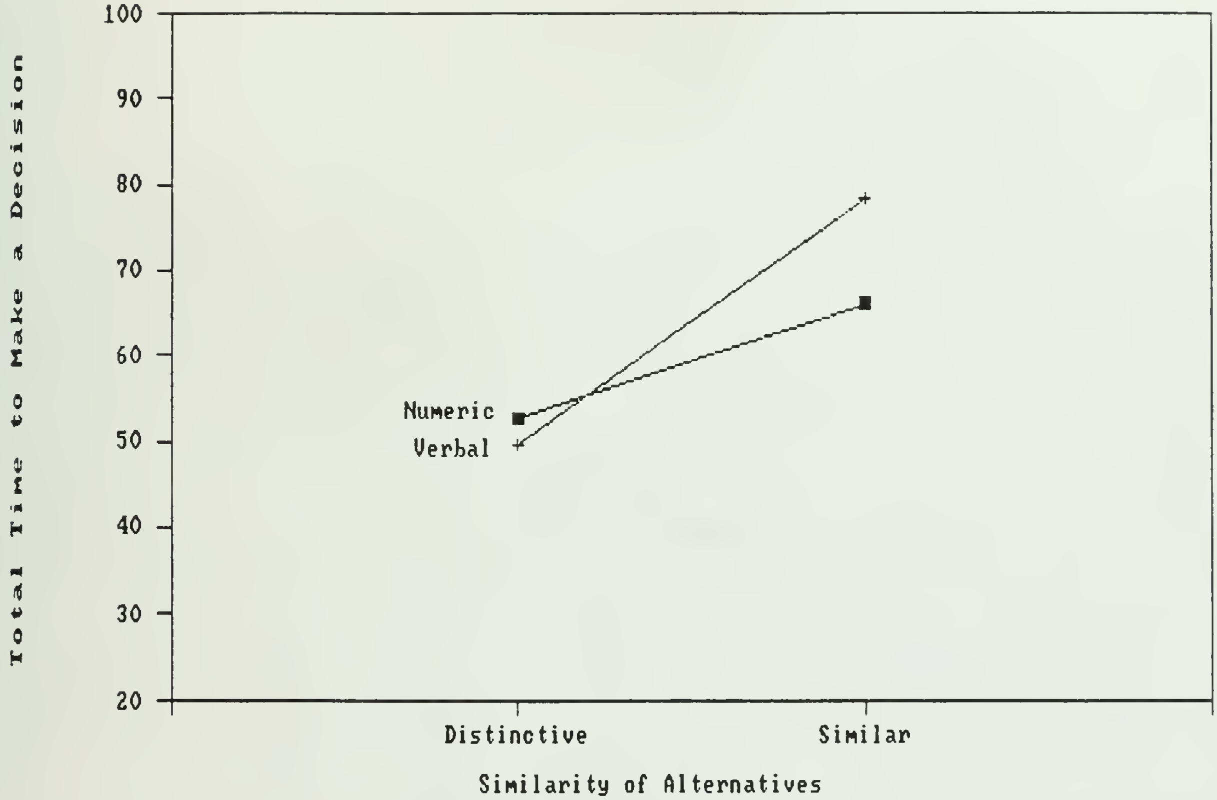
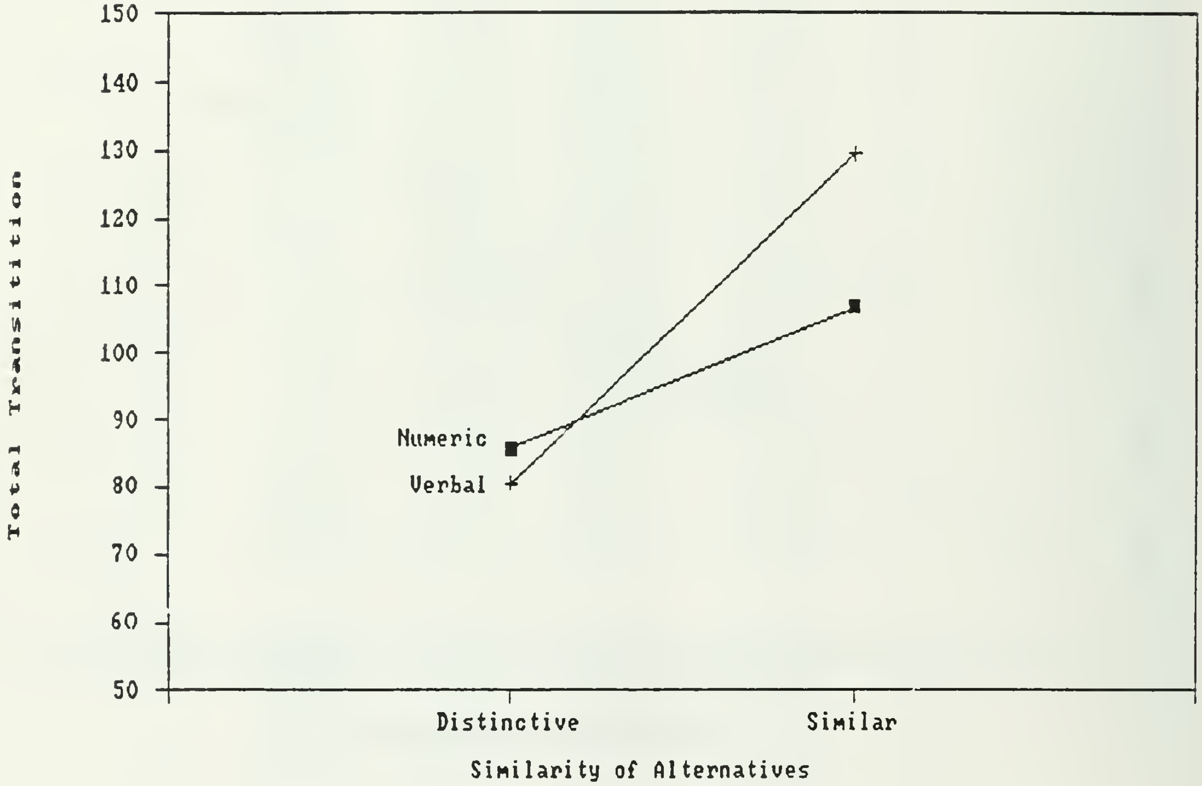


Figure 5 - Panel B

Total Transitions by Information Form and Similarity of Alternatives



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